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NOTES ON IRON AND STEEL.

BY
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Two subjects, which have been kindly suggested by the President of the Metallurgical Section of the Franklin Institute, will be discussed in our talk this evening; not because there is any especial relation between them, or continuity of thought, except in so far as they both deal with iron and steel, but because they represent somewhat more recent developments in the metallurgy of the world's commonest metal. These subjects are: the electrothermic manufacture of iron and steel, and the properties and uses of alloy steels.

THE ELECTROTHERMIC MANUFACTURE OF IRON AND STEEL.

The manufacture of iron and steel through the agency of heat produced by means of the electric current is an industry dating practically only from about the year 1900, although many experimental attempts were made before that time, and especially in connection with the production of ferro-alloys,—that is, alloys of pig iron used chiefly for the manufacture of alloy steels. The

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advantages of heat produced by means of the electric current over that produced by means of chemical reactions,—that is, from the combustion of fuels,—are four:

1. By means of electrically produced heat almost any temperature within reason may be obtained, and thus may be employed slags whose melting-point is too high for the commoner types of smelting (*e.g.*, slags very rich in lime and with a correspondingly strong affinity for those harmful impurities, phosphorus and sulphur), or ores which make the furnace charge too infusible for coke-smelting (*e.g.*, titaniferous iron ores in which a large amount of wealth is contained, but unavailable, in some of the northern parts of this country and in Canada), or there may be produced alloys too infusible to be made in furnaces heated by means of fuel-combustion (*e.g.*, ferro-titanium, ferro-tungsten, ferro-chrome or ferro-silicon richer than usual in the alloying element).

2. An exactness and nicety in the control of temperature so great that increased facility is given to the control of chemical reactions within the furnace, so that certain combinations of elements in the iron are made possible, and the temperature at which the steel is finished and cast may be more exactly regulated.

3. Freedom of the metal from contamination by certain impurities, such as sulphur, for instance, contained in the fuels ordinarily employed for smelting.

4. The availability of electric heat produced from water power in some localities convenient to ores and fluxes but where coal, coke, gas or oil may be obtained only at great expense.

The chief disadvantage of the electric production of heat for iron and steel smelting is the high cost of the electric current, which depends not only upon the cost of the power to generate it, but also, in several types of furnace, upon the consumption of the high-priced electrodes used to convey the current to and from the metallic bath. If it were not for this disadvantage of high cost, electrothermic smelting might be expected to rapidly replace fuel smelting for many purposes, and, even under the circumstances as described, it gives promise of a bright and important future, although not perhaps immediately.

In the successful types of furnace, the heat is obtained from the resistance offered to the passage of the electric current; those furnaces in which the arc alone is depended upon have not proved

satisfactory in practice. In iron ore smelting, carbon is the conductor whose resistance generates the heat; in refining of pig iron,—that is, in steel-making,—it is the melted metallic bath itself through which the current passes.

ELECTROTHERMIC IRON ORE SMELTING.

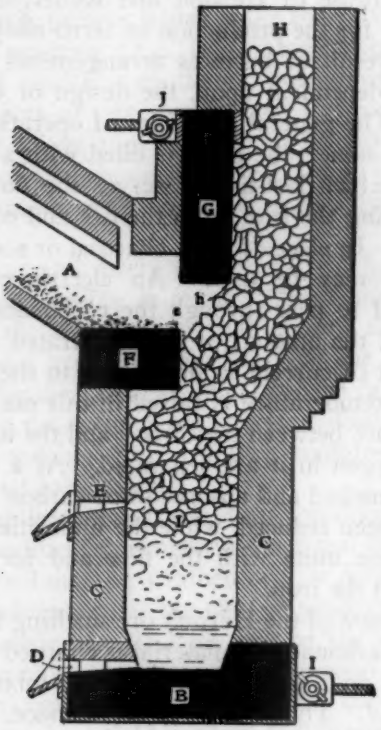
The two most successful electric furnaces for the production of pig iron are those of Héroult and Keller, the latter having been used chiefly for the production of ferro-alloys, although this happens as the result of business arrangements and is not connected with, or dependent upon, the design or operation of the furnace itself. The general principles of operation of both these furnaces are the same: the stack is filled with a mixture of ore, flux and coke, which last-named serves the double purpose of chemically reducing the iron from the ore and of conducting the electric current. In place of coke, charcoal or some other impure form of carbon may be used. An electric current of large volume is caused to pass through the carbonaceous material in the mixture, and the amount of heat generated thereby depends upon the amount of current in proportion to the amount of conductor. As the temperature is raised in this manner, a chemical reaction takes place between the carbon and the iron ore, whereby the iron and oxygen in it are separated. At a higher temperature, the iron is melted and absorbs some carbon and other impurities that have been reduced, while the impurities that are in the oxidized condition unite with the flux and form a liquid slag which floats upon the iron.

The arrangement of the Héroult ore-smelting furnace is shown in Fig. 1. The carbonaceous material is charged into the furnace in lumps at *H*, and, passing downwards, mixes with the ore which enters at *A*. The bottom of the furnace, *B*, is a block of solid carbon which is connected to the source of positive electricity at *I*. The current enters through *B*, passes upward, through the carbonaceous material in the charge, to the negative electrodes, *F* and *G*. As the iron is reduced and melted it collects in a liquid pool in the bottom of the furnace and is tapped when desirable through *D*, together with the slag which floats upon it. There are several Héroult furnaces used for smelting iron ore, and two have been successfully used in this continent.

The Keller furnace has a multiplicity of stacks filled with a

mixture of ore, flux and carbonaceous material, as shown in Figs. 2 and 3. These stacks, or shafts, are connected at the bottom by the channel *AAA*. The charge enters at *BB*, *BB* (refer now only to Fig. 2), and passes downwards in the furnace as smelting progresses. *H* and *K* are blocks of solid carbon; *H* is the positive, and *K* the negative electrode. *E* and *F* are also

FIG. 1.

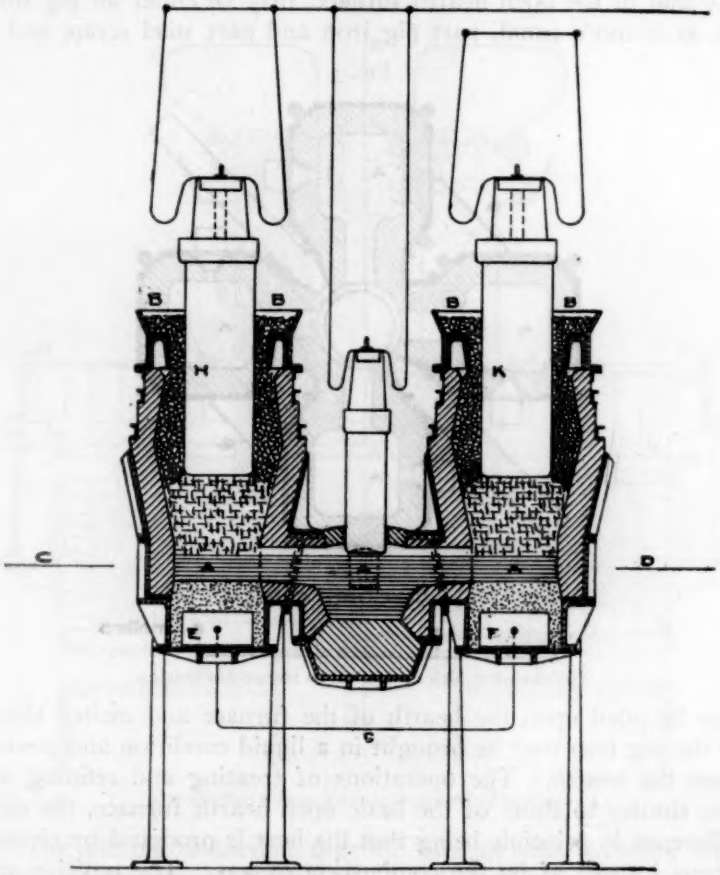


Héroult ore-smelting furnace (vertical section).

blocks of solid carbon which are connected by means of a conductor, *G*, passing outside of the furnace. The electric current enters at *H*, passes through the carbonaceous material in the charge to *E*, and thence by means of the outside conductor to *F*. It now passes through the carbonaceous material in the charge of the other shaft to the negative electrode, *K*. The same result in reduction and liquefaction of iron and slag takes place in each

stack as that described in connection with Fig. 1, and, as the pool of liquid iron collects in the channel *AAA*, it short-circuits the blocks *E-F*, and the electricity passes through this pool instead of through the outside conductor, *G*. In this way the liquid metal is kept hot until it is desired to tap it.

FIG. 2.



Keller electric high furnace with a plurality of open hearths.

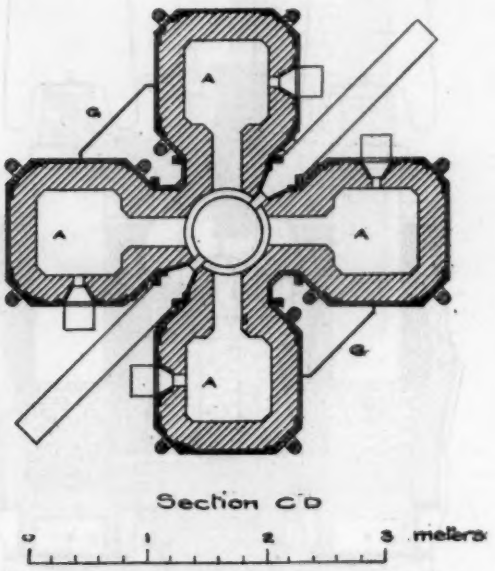
ELECTROTHERMIC MANUFACTURE OF STEEL.

The most important successful electric furnaces for the manufacture of steel are: the Héroult, or open hearth type, the Kjellin-Colby, or induction type, and the Gin, or trough type.

Of these the two former, which represent very different principles, both in the making of steel and in the use and application of electricity, have had the greatest amount of practical application.

The Héroult refining furnace is built very much like an open hearth furnace, as shown by Figs. 4 and 5. The charge, also like that of the open hearth furnace, may be either all pig iron, or, as is more usual, part pig iron and part steel scrap, and it

FIG. 3.

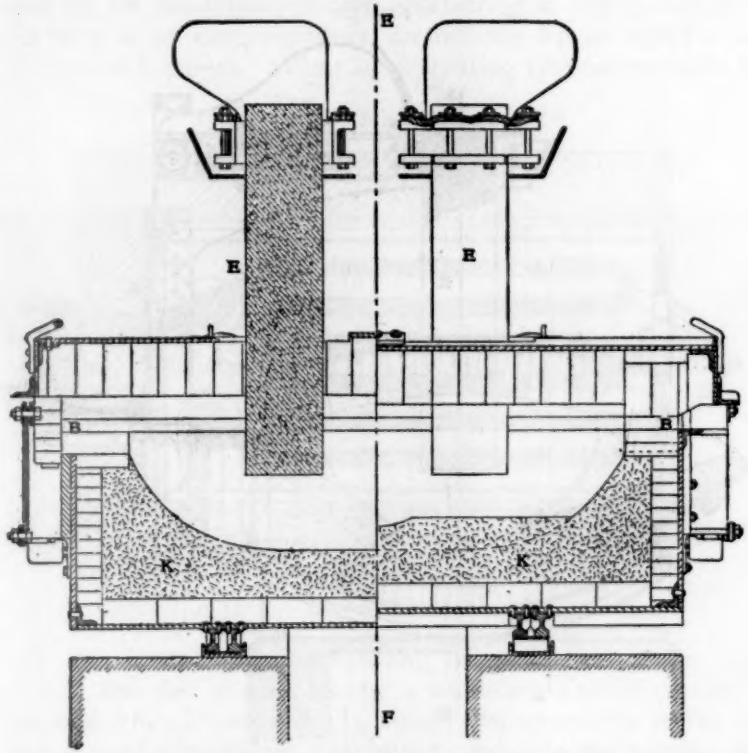


Keller electric high furnace with a plurality of hearths.

may be piled upon the hearth of the furnace and melted there, or the pig iron may be brought in a liquid condition and poured upon the hearth. The operations of treating and refining are also similar to those of the basic open hearth furnace, the only difference in principle being that the heat is produced by electric means instead of by the combustion of gas. The positive and negative electrodes, *E* and *E*, do not touch the bath, but the current arcs from the positive electrode to the bath, through which it passes and then arcs to the negative electrode. Thus heat is generated both by arc and resistance, but chiefly by the latter. The advantages of the Héroult furnace over the open

hearth are that any desired temperature, and therefore a greater variety of slags and fluxes, may be employed, with the consequent facility in removing certain impurities; that the temperature may be more easily controlled, and that the contamination of the metal by impurities unavoidable when heating by fuel combustion, is escaped.

FIG. 4.

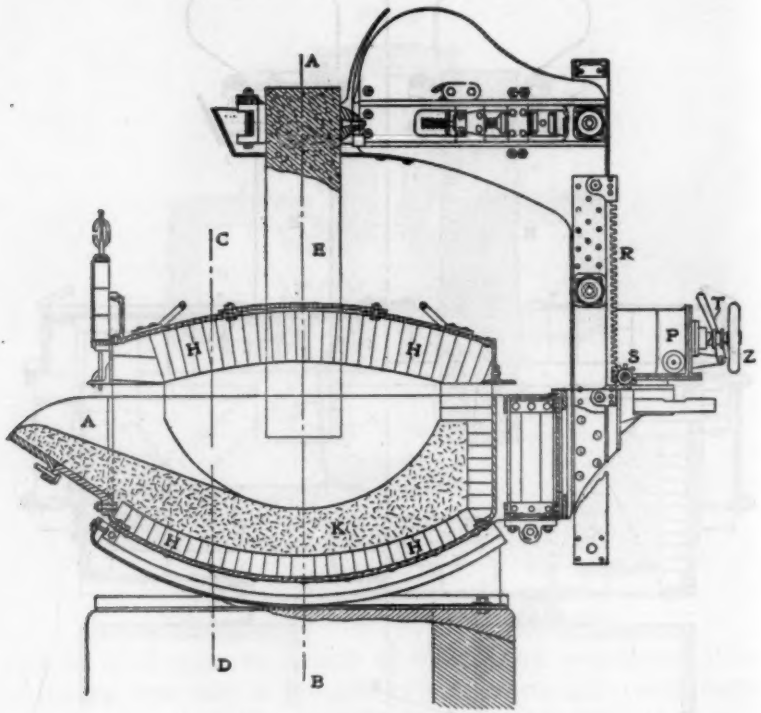


Héroult iron refining furnace (longitudinal sections).

The electric induction type of furnace was invented independently by F. A. Kjellin of Sweden and E. A. Colby of America. It is not a refining furnace, but consists essentially of a crucible in which metal may be melted by means of the heat generated by its resistance to the passage of an electric current. Before considering the somewhat complicated electric mechanism of the induction furnace, let us consider the same principle of

melting by means of the heat of electric resistance as applied in the Gin furnace (Fig. 6). Here we have a long trough which, for convenience, is doubled back and forth, and which contains the metal that is to be melted. The long, narrow, shallow trough of metal offers a large resistance to the current, and the heat generated thereby raises the bath to the desired temperature.

FIG. 5.

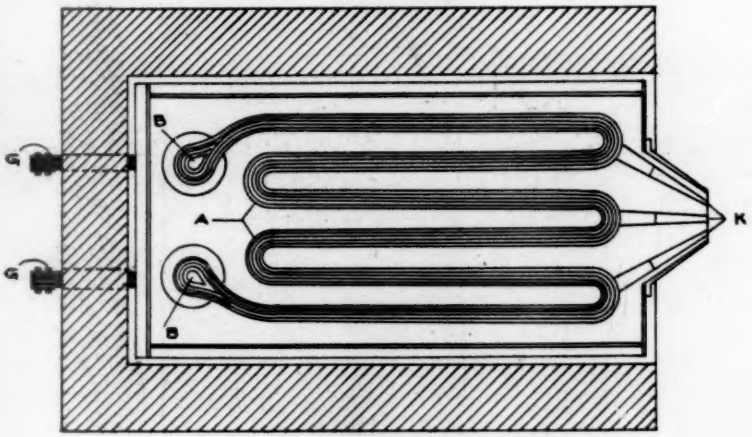


Héroult iron refining furnace (transverse section).

But the great difficulty with the design is that of making the electric connections to the melted bath. Carbon electrodes immersed in the bath at the points *B* and *B* are obviously impracticable, because such an arrangement would result in the expensive electrodes being absorbed and the metal unduly carburized. The difficulty has been met, but apparently not overcome, by making water-cooled electric connections at the points *B, B*.

The characteristic arrangement of the induction furnace is that all electric connections are unnecessary, and thus a great obstacle is overcome. The trough of this furnace is a circle (*B, B,* Fig. 8) moulded in block of fire-clay or similar substance, and covered with several little fire-clay covers (*K,* Fig. 7). This trough is really an annular crucible in which the metal to be melted is placed, after which a current of electricity is set up in it by the induction principle. Referring to Fig. 7, *CCCC* is the core of an electro-magnet, around one leg of which a coil of wire, *AA,* passes. When an alternating current traverses the

FIG. 6.

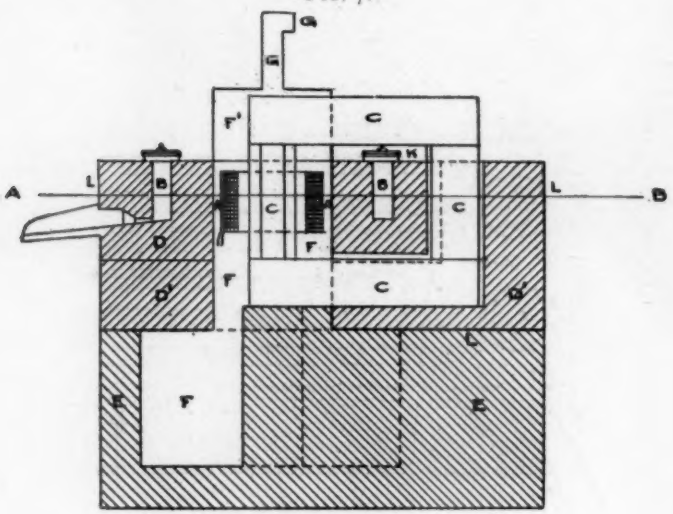


Gin electric furnace.

coil *AA,* it sets up an alternating magnetic field in the core, *CCCC,* and this in turn sets up a secondary electric current in the ring *BB.* In other words, an alternating current in the coil *AA* induces a secondary alternating current in the metallic circuit in the trough *BB,* without there being any metallic connection to it. The disadvantage of employing this principle is that the electric efficiency of the induction is very low, and therefore there is a large waste of current by the furnace, but the many advantages of the design have led to its adoption in several places for the purpose of melting down wrought iron with carbon and "physic" to make the grade of material known as "crucible steel." The cost of making crucible steel by the ordinary process

of melting down wrought iron, etc., in clay or graphite crucibles set in a coal fire or in a "melting-hole" heated by regenerated gas and air, or on the hearth of an open hearth furnace, is so great, on account of the short life of crucibles, the waste of heat, and the excessive labor, that the electrically heated crucible of the induction-furnace type can expect to compete in cost, while it has the advantage of being less liable to contaminate the metal with impurities in the fuel or furnace-gases, or in the walls of the crucible. The electric furnace also provides a better regulation of the temperature.

FIG. 7.



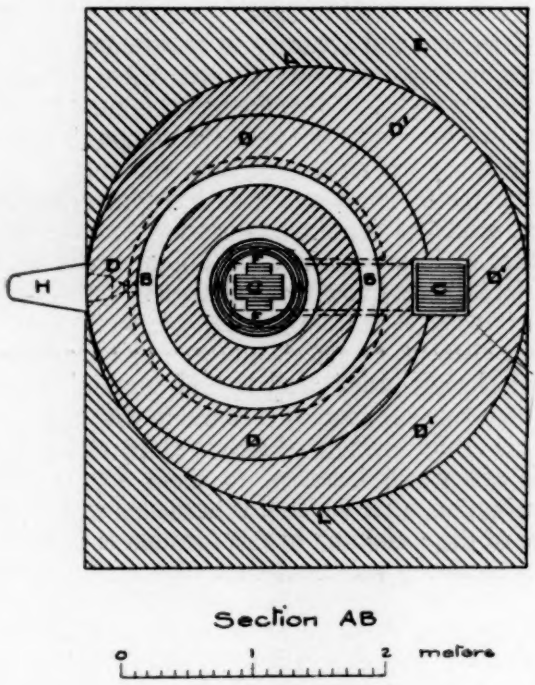
Kjellin furnace.

THE PROPERTIES AND USES OF ALLOY STEELS.

Nickel steel still retains the supremacy among the alloy steels as regards industrial importance and the amount used. Structural nickel steel contains usually about 0.35 per cent. of carbon and 3.50 per cent. of nickel. The presence of this much nickel increases the elastic limit of steel of this amount of carbon by about 50 per cent., while decreasing the ductility only about 15 to 20 per cent., and gives the material about six times the life in resistance to "fatigue." For these reasons it now finds use in the tension pieces of some important bridges, for parts of engines, especially piston rods, links, locomotive side frames and various

forged pieces, for shafting, especially marine shafting, for wire cables, for the frames of automobiles, which are now commonly made of this material, etc., etc. For castings, nickel steel has many points of superiority, including greater strength, greater liability to soundness, better crystalline structure, and less liability to checks and segregation. Nickel steel is harder than

FIG. 8.



Kjellin furnace.

carbon steel and has a lower coefficient of friction, and for these reasons it has found employment as axles, especially of locomotives and automobiles. The same strength of axle may be obtained in a smaller size, if of nickel steel, and this, because it reduces the area of bearing surface, still further reduces the frictional resistance. The hardness of the material finds use in railroad rails upon curves where the wear is extraordinary, while its greater resistance to corrosion finds use in boiler tubes and gas

engine valves. For the two latter purposes it is not uncommon to put as much as 30 per cent. of nickel in the steel. The expansion of the common grades of nickel steel is almost the same as that of carbon steel, but this quality is subject to great variation as the amount of nickel increases, and, when we have 36 per cent., it becomes almost zero with the daily changes of atmospheric temperature. Steel of this invariant character is patented under the name of "invar," and is used for pendulums of clocks and such like purposes. As steel measuring tapes for survey work it enables greater speed and accuracy to be attained at once, and permits working in important surveys even when the sun is up instead of during the night. When the nickel is further increased to 42 per cent. we have another patented compound known as "platinite," which has the same expansion and contraction with atmospheric changes of temperature as has glass. It can thus be used for the electrical connections passing through the glass plugs in the base of incandescent electric light bulbs, for which the only material hitherto known was platinum.

Chromium is used very little in steel except in combination with some other element, as nickel, tungsten or vanadium. The most important chrome-nickel steel is that containing 3.25 per cent. of nickel and 1.50 per cent. of chromium, with 0.25 per cent. of carbon. This is the formula of armor plate, and the outside of the plate is afterwards increased to about 2.50 per cent. of carbon by cementation, after which it is hardened with iced brine. The advantage of the chromium in this formula is that it greatly intensifies the hardness produced and also, with the nickel, increases the strength. The steel of armor-piercing projectiles also contains about 1 to 2 per cent. of chromium for the same reasons. Chromium, from 0.20 per cent. upwards, is sometimes put into gears and such like articles that are to be case-hardened, and the combination of chromium and nickel is used in steels for automobile crank-shafts and other articles requiring great strength. Steel with 3.50 per cent. of nickel and about 1 per cent. of chromium, after quenching in oil, or a double heat treatment, will often have well over 200,000 pounds per square inch tensile strength and elastic limit, with an elongation of 8 to 12 per cent. in 2 inches and a contraction of area of 30 to 40 per cent. Three-, four-, and five-ply steel is often made by sandwiching alternate plates of soft steel and of steel containing 1 per cent. of chromium

and 1 per cent. of carbon, tying into a "bundle," heating to a welding heat and then rolling down into bars for jails or plate for burglar-proof safes. These bars or plates after heat treatment cannot be drilled through on account of the layers of hardened chrome steel, and cannot be shattered on account of the layers of soft steel.

Manganese steel usually contains about 12 to 15 per cent. of manganese and from 0.70 to 2 per cent. of carbon. It is characterized by great strength and ductility (almost the only material known that has both of these qualities at once) and a relatively low elastic limit. It is hard under all circumstances, so that machining it is difficult, and indeed, impossible except to a very slight extent. It is also difficult and delicate to roll or forge and must usually be cast to the desired shape. When first cooled from the melted state it is not only hard but also very brittle; after reheating to nearly 1100° Centigrade and cooling as rapidly as possible in cold water or an iced mixture, it loses its brittleness and becomes tough and ductile, but still retains its hardness. Another peculiarity of it is that it is non-magnetic. It is used chiefly for articles that require to be hard and resist wear, but do not require much machining, such as railroad frogs and switches, burglar-proof safes, jaws and wearing parts of rock-crushing machinery, railroad rails on curves, etc.

The old "Mushet self-hardening steel," which is still used for machining where heavy, deep cuts are to be made, or hard material, such as armor-plate, is to be finished, but not at a rapid speed of cutting, owes its peculiar property of being hard and remaining hard without any heat-treatment, to the presence in it of nearly 2 per cent. of carbon together with both tungsten and manganese, or else tungsten and chromium. A common formula was: 1.85 per cent. carbon, 9 per cent. tungsten and 2.50 per cent. manganese. At the Bethlehem Steel Works Messrs. Taylor & White experimented with steels of this and other formulæ and discovered a heat treatment which not only increased their toughness but caused them to retain both their toughness and hardness at a red heat, so that they could do their cutting work at speeds so high that the point of the tool became red hot with friction. The amount of work they would do before regrinding was also increased. One feature of the heat treatment they employed was to heat the steel nearly to the scintillating point, and it was sub-

sequently discovered that this was the essential feature to attain the desired result. It was also soon learned that the formulæ of the steels used by Taylor & White could be improved upon, and the steels now employed usually contain well under 1 per cent. of carbon and from 12 to 24 per cent. of tungsten, with only 0.30 per cent. or so of manganese. Sometimes the tungsten is replaced by 10 per cent. or so of molybdenum, or else molybdenum

FIG. 9.

Colby induction electric steel furnace. Reproduced by the kind permission of the American Electric Furnace Company.

or chromium will be used together with the tungsten. The simplified heat treatment usually consists in heating the steel to about 1100° Centigrade and then cooling it with moderate rapidity, such as leaving it exposed in the open air or holding it in a blast of cold air. The name of "high-speed steels" has been given to these combinations, on account of the great rapidity with which they machine metals.

Steel containing 4 to 5 per cent. of tungsten and 0.5 to 0.70 per cent. of carbon, heated to 800° C. and quenched out in cold water, makes a more permanent magnet than ordinary carbon

steel treated in the same way. The tungsten can be replaced with about 2 to 3 per cent. of molybdenum, and sometimes we add 0.50 per cent. of chromium with either the tungsten or molybdenum, which will increase the permanency of the magnetism but reduce its initial force.

It had always been supposed that the purer the iron the better it was for the purpose of making electro-magnets, but Mr. R. A. Hadfield is the inventor of a steel which gives better results in this service than the purest iron it has been possible to obtain commercially. His steel contains 2.75 per cent. of silicon and the smallest possible amount of all other elements. Before this steel will show its characteristic magnetic properties, which include a high magnetic force, low hysteresis, and moderately high electric resistance (which latter reduces the "eddy currents" that are a source of loss in magneto-generating machinery), it must be subjected to a double heat treatment consisting of first heating to 1070° C. and cooling rapidly and then reheating to 750° C. and cooling very slowly.

The latest development in the line of alloy steels is that of vanadium steels, which in some cases have shown a wonderfully increased strength over carbon steel, and in other cases have proved somewhat contradictory. Nevertheless many engineers and manufacturers have been encouraged to go ahead, and many tons of this alloy have been made and used, while others have waited for further information. It would seem that vanadium is chiefly useful in very small doses,—not over 0.20 per cent. as a rule,—and also in combination with some other element as nickel or chromium. These combinations are particularly susceptible to the benefits of heat treatment, and great strength with relatively great ductility is sometimes obtained.

GROUND WATERS OF THE ATLANTIC COASTAL PLAIN.

INVESTIGATIONS IN PROGRESS BY THE GEOLOGICAL SURVEY.

The United States Geological Survey is making an investigation of the ground waters of the coastal plain of the Eastern and Southern United States, an area in which artesian waters are important in many industries. This investigation, which is under the general direction of T. Wayland Vaughan, includes not only an examination of the geologic conditions and structure that make artesian wells possible in this area, but also determinations of the quality and distribution of the waters and of their adaptability

for use for boilers, manufacturing, irrigation, and drinking. This work is being carried on in co-operation with State surveys in nearly all the coastal-plain States fom New Jersey to Texas.

WORK IN TEXAS.

The work in Texas is conducted by Alexander Deussen, of the geological department of the University of Texas, at Austin. The citizens of Texas who are interested in the economic development of the State can be of great service in this connection by sending to Mr. Deussen such data as may be in their possession concerning well logs, analyses of water, and the location, depth, capacity, and quality of wells, and also by furnishing samples of rocks and fossils (shells) taken from wells.

Reports on the investigations in Texas will be issued from time to time until the entire coastal plain of the State has been covered. The area east of Brazos River was the first to receive attention, and surveys are now in progress in the area between the Brazos and the Colorado. The report that will perhaps be of greatest economic value and interest to the citizens of the State will be that dealing with the artesian waters of southwestern Texas—that portion of Texas in which, by reason of its arid climate, artesian water is urgently needed for use in irrigation. The publication of these results should be a great stimulus to immigration and settlement in this new farming district. This work will be undertaken as soon as the other studies have been completed.

The results of the investigations east of the Brazos will be outlined in a paper that will soon go to press, entitled "The geology and ground waters of the coastal plain of Texas east of Brazos River." This report will deal particularly with water conditions but will also form an important contribution to the geology of the district.

PENNSYLVANIA ANTHRACITE.

The following statement regarding the anthracite industry of Pennsylvania has been prepared by Wm. W. Ruley, chief of the Bureau of Anthracite Coal Statistics, of Philadelphia. Mr. Ruley estimates that the shipments of anthracite for 1908 were 64,237,076 long tons, against 67,109,393 long tons in 1907, indicating a decrease of 2,872,317 long tons, or 4.28 per cent. Assuming that the quantity of coal sold to local trade and used at the mines decreased in the same proportion, the total production in 1908 amounted to approximately 73,200,000 long tons, as against 76,432,421 long tons in 1907.

The shipments of anthracite coal for the year 1908, although about three million tons less than for 1907, were nevertheless, next to those of that year, the largest in the history of the trade. A very considerable falling off in the demand was naturally to be expected in view of the depressed business conditions over all the country, and especially in the great manufacturing centres in the East, where anthracite is so largely used; yet the actual results were extremely gratifying, and indicate that, limited as the territory is for the consumption of anthracite, some curtailment in the individual demand was probably to a large extent offset by the increase of population in the anthracite-consuming territory.

About 80 per cent. of all the anthracite shipped is consumed in the New England States, Pennsylvania, New York, and New Jersey, or, in general, along the North Atlantic coast. The fact that the financial depression was probably more marked in this territory than in any other section of the country makes the relatively large consumption even more significant than might appear at first sight. It might naturally be supposed that the shutting down of so many industries and the consequent surplus of bituminous coal would result in a considerable decrease in the use of steam sizes of anthracite in competition with bituminous at the low prices. The facts, however, show

a strong demand for the steam sizes of anthracite at prices, generally speaking, better than those ruling in 1907, and reports in the trade indicate that on the restoration of normal conditions the use of small sizes of anthracite for steam purposes, by establishments preferring this coal on account of its cleanliness, will create a demand which it may be rather difficult to supply. The year 1909 will probably witness a consumption of both steam and domestic sizes of anthracite fully up to that of 1907, unless, of course, mining is interfered with by strikes or other extraordinary conditions.

A comparative statement of large and small sizes of anthracite shipped in the years 1907 and 1908, indicating the relative decrease in the production of the steam and domestic coal, is given below:

Year.	Domestic sizes.	Steam sizes.	Total.
1907	57,931,852	9,177,541	67,109,393
1908[1]	55,628,541	8,608,535	64,237,076

[1] December estimated.

THE CEMENT INDUSTRY IN 1908.

REDUCTION IN OUTPUT.

The following statement regarding conditions in the American Portland cement industry during the year 1908 has been prepared by Edwin C. Eckel for the United States Geological Survey.

Detailed figures are not yet obtainable, but an estimate based on the information at hand indicates that the production of Portland cement in the United States was somewhat less than forty million barrels. This compares as follows with the output of recent years:

	Barrels.
1905	35,246,812
1906	46,463,424
1907	48,785,390
1908 (estimated)	40,000,000

The falling off from the output of 1907 was heavy, and is particularly notable because it is the first decrease shown in any year of the American cement industry. The decrease was not uniformly distributed throughout the country, for New York, Pennsylvania, and New Jersey will probably show the highest percentages of loss, while in some portions of the West and Middle West the decrease was relatively slight.

During the year several small companies went into the hands of receivers and the financial stress also led to a change of control in a group of plants operating chiefly in the Pacific States. A fortunate effect of the depression was that it put a stop, temporarily, to the flotation of fraudulent or doubtful cement securities; though it is likely that with improvement in general business conditions promotion schemes will again be taken up on an even larger scale than before the depression.

The year 1909 opens with heavy stocks of cement on hand at most mills, but with good prospects for a steady though slow revival in the cement trade. It is unlikely that this revival will be sufficiently rapid to push mills to their capacity during the year, and it is therefore possible that the high record for output made in 1907 will remain unbroken for another year at least. The total maximum capacity of existing plants is now about 60,000,000 barrels a year.

Despite business depression, or perhaps partly because of it, there have been a number of important technical and industrial developments in the cement industry during 1908, and others are still pending. These will be discussed in the Survey's annual report on cement production, to be issued early in the spring.

SECTION OF PHYSICS AND CHEMISTRY

(Stated meeting held Thursday, January 14, 1909.)

SOME NOTES ON QUININE AND ITS ASSOCIATED ALKALOIDS.

BY
DR. E. GOLDSMITH,
Member of the Institute.

THE material from which quinine and its associated alkaloids are obtained is the bark of the cinchona tree.

On the west coast of South America, on the slopes of the Cordilleras de los Andes, Peru, Bolivia, and to some extent in Central America, the trees were found, felled, and stripped of their bark; this was packed into seroons and shipped to the markets of the world.

It seems that in 1640 the cinchona bark became known in Europe, but it took nearly one hundred years before the naturalist traced out the plant from which the bark was derived. Since then a considerable number of species of trees became known, each furnishing its own variety of bark. Botanists visited the localities in the Cordilleras; even Alexander von Humboldt interested himself in the subject and drew and published a map to show the extent and the geographical position of those valuable trees.

It is noteworthy to state, that the trees in question have been nearly exterminated from South American localities. Bogota and New Granada yielded some bark supplies for the market; but the people of South America have ruthlessly destroyed the plants, because they never replanted any of the cinchonas, and consequently lost the market of the world forever.

The supply of the bark is now derived from the cinchona plantations of the East Indies. These are situated on the southern slopes of the Himalaya Mountains, in the Punjab region, where the trees have been cultivated for over thirty years, and the yield of the bark and the alkaloids increased. On the Sunda

Islands, Sumatra and Java, also to some extent on the West India Islands, experimental plantations have shown that the cinchonas may successfully be grown. I am not aware that any of these trees have ever been raised in the United States. The public press in years gone by indicated that in the western mountain regions such cinchona plantations would be started; whether it was ever done is unknown to me.

Several firms in Holland handle the bulk of the cinchona bark and seem to have the monopoly of the trade in it. Since the introduction of the East India cultivated bark the supply of the drug has enormously increased.

For one hundred years or longer the bark as such was dispensed to suffering humanity. However the mixture was prepared, the ugly woody fibre had to be chewed and swallowed. I remember about fifty-five years ago I had to eat some of the ugly stuff to abate a certain trouble. Not long ago I was told by a druggist that certain practitioners adhere still to the old idea of prescribing the bark in powder form.

Not all the cinchona bark offered was accepted for the extraction of quinine it might contain; the bark had to yield more than one-half per cent. of sulphate of quinine, and this was the limit for a great many years during my experience.

It did not pay to buy the poor bark, at least not in this country. Therefore, prior to the purchase of the lots offered, the article had to be sampled and analytically determined.

Quinometry differed with the analyst. My process was as follows:

The samples were finely ground in a mill, well mixed, and one thousand grains' weight mixed with some slacked lime and alcohol and introduced into a steam-jacketed copper apparatus having a false bottom. From the solution the alcohol was distilled and returned over the sample of bark until the extraction of all the alkaloids was completed. The dry mixture of these was then transferred into a four-ounce glass-stoppered bottle, 5 c.c. of ammonia water and sulphuric ether free from alcohol were poured over it, agitated, left standing to settle, and, when clear, the ethereal solution was allowed to run into a porcelain dish. This treatment with ether had to be repeated to secure the complete separation of the quinine from the other alkaloids not so readily soluble in this menstruum. However, it is well known

that cinchonidia is also soluble, at least to some extent, in the ether. The ether was allowed to evaporate spontaneously.

The residue is now free from inorganic matter and cinchonia; but it may contain cinchonidia and more or less uncrystallizable colored matters, which have to be separated. In order to accomplish this in a proper manner, the alkaloids have to be dissolved in diluted sulphuric acid. This must be done with care at the boiling point, in such a manner that only a very slight acid solution is obtained. The hot solution is quickly filtered through paper with the aid of the suction pump, concentrated by heating over the Bunsen flame and constant agitation, and the slight excess of sulphuric acid is carefully neutralized with dilute aqua ammonia. If now the correct concentration has been reached, which the analyst can judge better than describe, he will, on further agitating the solution to coolness, obtain a thick and almost complete crystallization of the sulphate of quinine; that is to say, if this salt is present. But, should he observe that a slow mushy mass of a compound drops out, he must suspect cinchonidia sulphate, with or without sulphate of quinine. The massy crystallization was usually allowed to stand a number of hours prior to washing and filtration.

Cold water will take up the coloring matter into solution. The same is the case with the cinchonidia sulphate if present, provided the mass is worked to force these matters to dissolve.

Since sulphate of quinine is very little soluble in cold water, it is comparatively easy to separate it from the other two substances. The washing with small quantities of cold water and forcing the colored solution through the filter paper with the suction pump help to remove the undesirable matter from the sulphate of quinine. When this has been accomplished, the filter holding all the quinine salt is lifted from its support and pressed between absorbing paper nearly to dryness. The complete drying is effected in the steam-heated oven.

After drying and cooling, the sulphate of quinine is removed from the filter and weighed. The alkaloids which the sulphuric ether had not dissolved were converted into sulphates and the clear solution mixed with a slight excess of aqua ammonia to cause them to drop out. They were filtered off, washed, and dried, and finally weighed.

Cinchonia was found, but sometimes also cinchonidia was

recognized. If cinchonidia was found and it was required to determine the same quantitatively, I had recourse to the Rochelle salt reaction.

To measure anything correctly is an art which has to be acquired by practice. But, the best analyst can do no more than do his duty faithfully.

How is he, the analyst, made responsible for the sampling which duty is left to the common laborer in the warehouse without any proper instruction? The laborer is not controlled by a superior or by sound common sense. He is ordered to take from every five or ten seroons a handful of bark, put the same into paper, which has been previously marked, and these samples are sent to the buyer for inspection and analysis. This system has been in practice for many years.

Here I may mention my experience with the celebrated calisaya bark, which was supposed to be the best bark for the manufacture of quinine. The statement has often been made in print that from 2½ to 3 per cent. or more of quinine may be relied upon, but I have found that occasionally this very bark is worthless on account of the small quantity of quinine contained therein. To purchase, therefore, any kind of bark on sight and reputation is risky.

The South American bark gave in the average not more than about 1½ per cent. of sulphate of quinine. The cultivated East India bark of the cinchonas has in general a higher percentage of the desirable alkaloids. It seems to me that the formation of sulphate of quinine in the evaluation of the bark is the most practical form in which the determination may rest.

In regard to the so-called manufacture of sulphate of quinine and the separation of the accompanying alkaloids on a large scale, from the time of the second decade of the nineteenth century to the present time, I dare say, the process has undergone a great evolution. The changes in the apparatus used and the introduction of modern machinery have been considerable. I have seen wooden tubs without lining and sometimes lined with sheet lead, used as the apparatus in which the crudely powdered bark was treated with diluted sulphuric acid to exhaust the woody fibre containing the alkaloids. Sometimes hydrochloric acid was preferred for the same purpose, and then the solutions were treated with milk of lime or carbonate of soda to obtain the alkaloids in the solid form.

Experimental work proved that the exhaustion of the bark in an alkaline mixture gave a better and more satisfactory result when alcohol was used as the solvent. To some extent the alcohol could be recovered.

Then followed a great improvement in the fifth decade of the last century in the application of fusel oil as a solvent of these organic bodies. The fusel oil was then not only low in price for a time, but it possesses an oily property admirably adapted to hold the alkaloids in solution, from which they may be readily separated by diluted sulphuric acid.

This property, a trans-solution from one solvent to another, is of a high practical value; because it furnishes at once, with one stroke as it were, a concentrated watery solution of the whole of the alkaloids contained in the cinchona bark.

It is self-evident that this magnificent property, just described, was quickly recognized by those who were engaged in the business of the production of sulphate of quinine. The demand in the markets for fusel oil became in consequence so great that its price rose and here in the United States the supply became inadequate. It became necessary to import it.

Since the amyl alcohol is a secondary product of the alcoholic fermentation, the supply is limited and even the European market has never been overstocked with this useful and interesting solvent.

In 1869 my thoughts were directed to find a substitute for the fusel oil. The cheapness of certain paraffin oils at that time induced me to study their properties as solvents to the quinine group of alkaloids. I observed that certain of those paraffin oils could be utilized for that purpose. I saw that the invention was valuable to the manufacturer of the alkaloids; but my suggestion to utilize paraffin oil was not adopted,—for various reasons,—until a period seventeen years subsequently, when an agent of a paraffin oil producer induced the manufacturer to adopt the oil with which I had experimented, with a result of about one-twentieth of the cost of fusel oil for the extraction of the alkaloids. From this time on, we have the last step in the evolution of the extraction of the alkaloids from the cinchona barks.

You see, therefore, that this work had four periods: the acid period; the ethyl-alcohol period; the fusel-oil time, and finally the paraffin-oil step. It is probable that the paraffin oils are still in use for the general extraction of the alkaloids from the bark.

The next step is to separate the alkaloids from the oil.

If the oily solution is highly concentrated and the temperature is low, it may happen that parts of the alkaloids drop out in a flocculent or sometimes a crystalline form. Now diluted sulphuric acid is added, in which the alkaloids dissolve readily. When this is effected, we obtain two layers, the oily above and the watery sulphate solution below. The oily stratum above is separated from the slightly acid sulphate solution and is ready again for the next extraction, and so on *ad infinitum*.

The acid sulphate solution, which we assume to be rich in sulphate of quinine, now undergoes a fractional precipitation. If we carefully neutralize the solution and agitate, sulphate of quinine becomes insoluble,—that is to say, drops out. This fact, well known for a good many years to the specialist of the article in question, is, so far as I had occasion to converse with chemists, not generally known to my chemical confrères, and for this reason it is put here in evidence. The theory is simple. Since the basic sulphate of quinine is the most insoluble salt of the whole series of alkaloids of the cinchona barks, it becomes evident that, by careful neutralization of the sulphuric acid, the difficultly soluble salt separates first, while the other sulphates remain in solution.

The sulphate salt formed may now be separated from the more soluble parts either by filtration through muslin strainers or the centrifugal machine or the filter press. In either case the dark-colored mother-liquor is separated from the basic sulphate salt more or less completely. If a centrifugal machine or a filter press is used, a washing with cold water may be resorted to with good effect.

Although by the above means the coloring matter is mostly removed from the basic sulphate salt, we obtain usually a grayish or slightly yellow crystalline mass which readily dissolves in boiling water still somewhat colored.

In order to decolorize the solution, recourse is had to fresh fine-ground bone-black. Some manufacturers employ a bone-black freed from the phosphate of lime; others use the ordinary kind. The bone-black is simply mixed into the solution, and the filtration commences either under ordinary atmospheric pressure or with the aid of artificial pressure. These variations are matters of choice, and in various ways it is possible to obtain a per-

fectly clear solution of high concentration of the sulphate of quinine; but in general the solution has a straw-colored tint from which the white feathery masses crystallize on cooling.

The vessel in which the solution is effected is generally a wooden tank lined with sheet lead. The heating is done either by blowing live steam into the solution directly, or a coil of lead pipe is arranged within the tank through which the live steam under pressure circulates, to cause the solution to boil. The vessels in which the crystallization of the sulphate salt takes place are also built of wood and lined with sheet lead.

If any sulphate of cinchonidia goes into the crude sulphate of quinine, then the mother-liquor from the first fine crystallization contains the cinchonidia salt along with some of the quinine.

The further separation of the various alkaloids from each other belongs to operations which would lead us into a discussion not here intended.

The alkaloids under discussion seem to possess, like the sugars, the property to hydrolize. If the diluted solutions are boiled, to drive away the water,—that is, to concentrate them,—they gradually lose the power to crystallize. This fact being known, diluted solutions are not concentrated by boiling. The alkaloids are either precipitated by carbonate of soda, then filtered off and washed, or recourse is sometimes had to the trans-solution into fusel oil, from which a concentrated acid solution may be obtained at ordinary temperature.

I may state here that in general the separations are effected according to the predominance of any of the alkaloids present in the mixture.

When the solution will not crystallize any more, we have what has been called quinoidine, apparently an amorphous mass. For forty years or more this quinoidine—which had but little sale—was collected.

In 1872 I made an investigation of the apparently amorphous mass, and found that, in reality, a large part of it could be induced to crystallize if treated with Rochelle salt. If the nearly neutral solution of the sulphate of quinoidine be treated with a strong solution of Rochelle salt, a crystalline mixture of tartrates of cinchonidia and quinidine is obtained. To be sure, the tartaric acid was recovered, and the alkaloids could then be brought to crystallize after proper separation and refining.

In 1873, during the panic, the whole of that forty years' collection of quinoidine was worked over. Over two millions of dollars were realized out of it. But since that time all the quinoidine was regularly got rid of by the process above described. Of course, the space gained could be utilized for other purposes.

As stated above, the method of separation of the different alkaloids depends upon the greater or less quantities in which these occur in the mixture. If cinchonia predominates, it must be removed by crystallization or by partial precipitation first; and the same with the others. It follows from this that the workings have to be continually under the systematic control of an expert in this particular line; and, indeed, he who has charge of a large plant to furnish 25,000 ounces of sulphate of quinine per week is pushed to move continually to separate the quinidia, the cinchonidia, and the cinchonia; otherwise the vessels of the plant would soon be all filled to overflowing; which must be avoided.

In 1875 a crystalline mass, supposed to be sulphate of cinchonidia, had not crystallized in the normal form. The crystals were colorless and gelatinous. Such a matter had been recorded before; but no further investigation had been made and no distinct reaction given. It occurred to me to seek for some facts to establish its identity, if possible, and to name it, whatever it might be.

The crystals were separated from the gelatinous mother-liquor. As long as they were moist they were transparent, with a glossy reflecting lustre. Dried in the air between folds of paper, they became opaque and fell to a white powder which seemed to be microcrystalline. The transparent form of the substance is therefore not constant in the air.

The alkaloid may be separated from the sulphate by ammonia. After washing with water and drying we have a white powder.

A hydrochloride may be formed by dissolving the precipitated white powder in hydrochloric acid. The hot concentrated and neutral solution of this hydrochloride on cooling will crystallize in long slender silky prisms; in fact, the crystals extend from end to end of the vessel in which they are formed.

Now, if these crystals be allowed to remain in the vessel during several days, a transformation takes place, such that short, stout monoclinic octahedra make their appearance. In order to see whether the same phenomena would reappear, I repeated the same process again and again with the same result.

As far as I knew, this property of paramorphism, so well defined in this rather rare alkaloid, is distinct from any of the others in the group.

At the time I contented myself to hunt over the records and did not follow the subject further, partly for want of time and partly on account of a promise given not to publish anything observed in the chemical works. I did prepare the gold salts and also the platinum salts of the alkaloid, and, in the determination of the metal contained in each of them, I became convinced that I had found a new alkaloid.

In 1876 a conference took place, in the Main Hall at the Centennial Exposition, between myself and a chemist who worked in the same line and who had made some observations in a similar matter; that is to say, on an alkaloid which, as he expressed himself, gave a gelatinous sulphate. I suggested that he should send a sample of the material to O. Hesse, in Germany. This gentleman had a position in a sulphate of quinine works with the right and liberty to investigate not only but also to publish his results.

Five years afterwards he published the result of his investigation, in which the fact appeared that the alkaloid under consideration was distinct. O. Hesse named it para-cinchonidia. The author made an ultimate analysis of the substance, and reported that it contained 19 molecules of carbon, instead of 20 molecules, which some of the other bodies, as quinine, etc., hold.

It is probable that I was the first to recognize this rather rare new alkaloid, but I do not claim any priority, because I did not publish anything before 1881; I was simply prevented by a promise made to a manufacturer.

The formulas of the foregoing alkaloids are:

Sulphate of quinine, $(C_{20}H_{24}N_2O_2)_2.H_2SO_4 + 7H_2O$
Sulphate of quinidine, $(C_{20}H_{24}N_2O_2)_2.H_2SO_4 + 2H_2O$
Sulphate of cinchonidine, $(C_{19}H_{22}N_2O)_2.H_2SO_4 + 5H_2O$
Sulphate of cinchonia, $(C_{19}H_{22}N_2O)_2.H_2SO_4 + 2H_2O$
Sulphate of para-cinchonidine, $(C_{19}H_{22}NO)_2.H_2SO_4 + 2H_2O$

SECTION
OF PHOTOGRAPHY AND MICROSCOPY

(Stated meeting held Thursday, January 7, 1909.)

THE DAGUERROTYPE, THE AMBROTYPE, AND THE PHOTOGRAPH.

BY
WILLIAM O. GRIGGS, M.D.,
Member of the Institute.

THE word 'photograph' is obtained from two Greek words—photos, light, and graphos, to write. Photography is the art of producing pictures by the action of certain sensitive substances under the action of light. It is said to have sprung from the discovery, some 300 years ago, that the luna cornea of the alchemists (fused silver chloride) would darken on exposure to light. Nothing more was known about this until in 1777 Scheele, the Swedish chemist, noticed that the power which produced this darkening resided chiefly in the violet end of the solar spectrum; this led to the use of nonactinic or red light in which to handle the sensitive plates, especially while developing and fixing them. The difficulty of fixing the pictures was one of the early troubles experienced; this was finally overcome by Sir John Herschel, who suggested the use of hyposulphite of soda.

The photographic picture is obtained in the daguerrotype process on polished metal plates, either of silver or of copper coated with silver.

Calotype is produced on paper,

Albumin on a film of albumin on glass,

Collodion on a film of collodion on glass,

Gelatin on a film of gelatin on glass.

The daguerrotype process was discovered by Niepce and Daguerre, and in short is as follows: A silver or silvered copper plate is highly polished and placed in a dark room on a china dish containing iodine. The vapor of this substance combines with the silver of the plate and produces iodide of silver, a sub-

stance sensitive to light. This wonderful discovery, like many others, was the result of an accident. Daguerre had iodized some silver plates to use for an experiment he was making and carelessly left a metal spoon lying on one of them; upon raising the spoon some time afterwards, he found its image clearly impressed upon the plate. From this he learned that iodide of silver was sensitive to light, and after a few more experiments the so-called daguerrotype was produced.

One of the first difficulties that Daguerre encountered was to have the plate properly polished. This was finally successfully accomplished by August Brassart, a silversmith of Paris, who sought out Daguerre and volunteered his services. It is stated

Tree-frog snapshot, Seeds 26 x plate. By Dr. Wm. O. Griggs.

that when the first successful picture was made, Daguerre embraced his assistant and fainted in his arms. Brassart died in St. Louis, Mo., early in August of this present year (1908) and a short historical notice of him appeared in the *Philadelphia Inquirer* of August 10, 1908.

The next difficulty that beset Daguerre was properly to develop the picture. The discovery which solved this difficulty was also the result of an accident. He had made a number of exposures and was as many times discouraged by his want of success in developing his pictures. One day he placed an exposed plate in a closet, intending at some future time to take it out and clean it and resensitize it. After leaving it there for a considerable time, he removed it, and was very much surprised to find the picture beautifully developed. But as there were a number of articles in the closet he did not know to which to attribute the

wonderful result. He then began to remove the articles one by one and after each removal he placed an exposed plate in the closet, and still the development went on. Finally after having removed everything he again placed an exposed plate in the closet and was again surprised to find the picture perfectly developed. After making a critical examination of the interior he discovered that some mercury had been spilled on the floor and rightly conjectured that the vapor of the mercury had caused the much-

Winona Falls Nos. 1, 2 and 3, Pike Co., Pa. Snapshot, Carbutt's Eclipse plate 27
By Dr. Wm. O. Griggs.

desired result; and further experiments proved this to be true. The picture was finally fixed or made permanent by dipping it into a weak solution of hyposulphite of soda.

To Giambattista della Porta, a Neopolitan philosopher of the latter part of the sixteenth century, belongs the honor of having been the first to contribute to the optics of photography an apparatus by which the size of the picture and its proper registration on the plate could be controlled. This was called the camera obscura, or camera as we term it at the present time, an article which is so common to you all that it is not necessary to describe it.

There is some controversy about the early history of the daguerrotype. It was so slow a process that it was possible to use it only for still-life pictures until the discovery that bromine used instead of iodine for sensitizing the plates rendered them speedy enough to permit of making portraits. The honor of this discovery undoubtedly belongs to Dr. Paul Beek Goddard, of Philadelphia, as in a paper read by him before the American Philosophical Society in 1843, he described the bromide process, exhibiting at the same meeting a daguerrotype which he said

Winona Falls No. 5, Pike Co., Pa. Snapshot, Carbutt's Eclipse plate 27.

he made by that process in December, 1839. Dr. Goddard was known to be a man of sterling integrity and truthful in his statements. This account is published in the Transactions of the American Philosophical Society, vol. 3, page 180. This society was composed of men of eminence in science and character, who would not allow any statement of a doubtful nature to appear on the pages of their journal.

The calotype process was the invention of Mr W. H. Fox Talbot. It consists in spreading on a sheet of paper first a solution of iodide of potassium and then a solution of nitrate of silver; these react and produce iodide of silver in the pores of the paper. The paper is then well washed in water, contained in a porcelain basin, to remove the excess nitrate of silver. If this

paper is exposed to light, the iodide of silver will blacken. The picture is fixed by the use of hyposulphite of soda. The calotype pictures are all what are called indirect or negative pictures, and Talbot was the first to use the terms negative and positive.

The albumin process consists in dissolving a small quantity of iodide of potassium in properly prepared albumin obtained from white of egg. This is spread on a well-cleaned plate of glass, the dried glass is immersed in a solution of nitrate of silver, exposed to the light in a camera, and developed in the same way

Water lilies from Echo Lake, Monroe Co., Pa. Exposure 1 second, Stanley plate 50.
By Dr. Wm. O. Griggs.

as the calotype; that is, by using a mixture composed of a solution of gallic acid and a weak solution of nitrate of silver to which a little acetic acid has been added; it is then fixed as usual with hyposulphite of soda. The advantages of this process are that the details are finer and the objectionable grain of the paper is avoided. It is not suitable for portraits, as it is not very sensitive, requiring about ten minutes in a good light to produce an impression.

The collodion process, which employs a film of collodion properly treated with the iodides and then immersed in a nitrate of silver solution, has the great advantage of being at least sixty

times more sensitive than the albumin process and much easier of execution.

The next successful style of picture after the daguerrotype was the ambrotype, from the Greek words ambrotos, immortal, and typos, an impression. This was made on glass on which a properly prepared collodion had been spread, the lights being represented by silver and the shadows produced by a dark background visible through the unsilvered portions of the glass. The ambrotype collodion was composed of

Collodion	8 oz.
Bromo-iodide of silver	6 dr.
Hydrobromic acid	6 drops

The manner of procedure is to make a bath containing 40 grains of nitrate of silver to the ounce of water. The bromide of silver is made by mixing

Bromide of potassium	80 gr.
Nitrate of silver	80 gr.
Water	4 oz.

Dissolve the salts separately, then mix and wash in three changes of water and two of alcohol, then powder iodide of potassium 1 ounce and dissolve in alcohol 8 ounces and add to the above mixture.

Hydrobromic acid is made by taking

Alcohol (95 per cent.)	4 oz.
Water (distilled)	1 oz.
Pure bromine	1 dr.

Shake well and add to the collodion. The collodion is flowed over the glass plate and the plate dipped into the nitrate of silver bath. It is then exposed in the camera, developed with either gallic acid or sulphate of iron, and fixed in the usual way.

The first photography such as is used at the present day—the making of a negative in the camera first and then printing the positive picture from that negative—was done by what is known as the wet-plate process, so called because the plate was sensitive only while wet. This method was as follows: After cleaning the glass thoroughly it was given a coat of albumin by pouring over the plate a mixture of well-beaten white of egg and water. The plates after having been dried were put away and secured from dust. It was found that the collodion used in

the next part of the process flowed more evenly and easily over a plate thus prepared. The collodion was prepared in the usual way by dissolving gun cotton in a mixture of alcohol and ether. The proportions are:

Ether	3 oz.
Alcohol	1½ oz.
Gun cotton	16 grs.
Iodide of cadmium in powder	18 grs.
Bromide of cadmium in powder	6 grs.

This was then flowed over the plate (by pouring it on the middle and then tilting the plate in different directions until entirely covered, when the collodion was poured off from the lower right-hand corner) and after it was set it was lowered into a bath composed of 2 ounces of pure crystallized nitrate of silver and 24 ounces of distilled water. The plate was raised from time to time from the bath and examined; if it presented a greasy appearance or showed lines upon it, it was returned to the bath until it presented a smooth homogeneous surface. It had to be placed in the camera and exposed at once while still wet. The plate was then immediately developed by pouring over it a solution composed of

Protosulphate of iron	1 oz.
Acetic acid	12 drops
Distilled water	1 pint

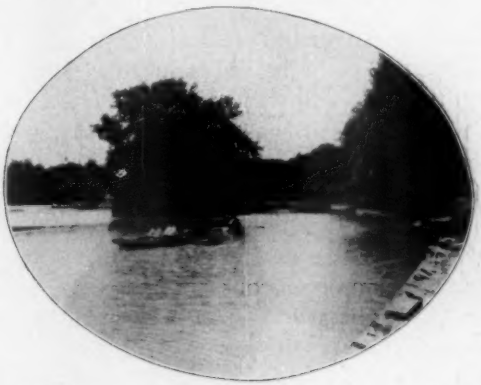
after which it was fixed in a bath composed of

Hyposulphite of soda	3 oz.
Water	1 pint

This process requires such cumbrous apparatus that it is unsuited to the needs of the present day and is very little used except for lantern slides and window transparencies.

Since the advent of the gelatin dry plate, photography has made wonderful strides both in the picturesque and the useful. One of the good features of these plates is that they can be transported to great distances. They may be developed at leisure even months after having been exposed. Another great advantage over the old wet plate is their great rapidity. Until very quick plates were made it was impossible to correctly picture animals in motion. The first successful pictures of this kind were made by Mr. Muybridge. Some of our recent snapshots

of horse-races prove the old idealized pictures of trotting horses to be mere caricatures of the truth, as these old pictures show the horses in all sorts of impossible attitudes. Rapid plates are also of use in photographing lightning flashes correctly—some of Doré's illustrations of lightning in Dante's "Inferno" resemble a zigzag staircase more than anything else. One of the pioneers in making pictures of lightning flashes was Mr. W. N. Jennings, of Philadelphia.



Peters Island, Schuylkill River. Snapshot taken against the sunlight, Carbutt's Eclipse 27
By Dr. Wm. O. Griggs.

The first manufacturer of dry plates in Philadelphia was the late Mr. John Carbutt, a member of the Franklin Institute and one of our colleagues in the photographic section. Dry plates are made in three classes—slow, medium fast, and very fast. The very slow chloride plates are used for lantern slides and window transparencies; the medium fast, for landscapes, machinery, and architectural subjects, etc.; while the most rapid plates are used for portrait and snapshot or instantaneous work, and X-ray pictures.

Window transparencies and lantern slides are made in two ways. One is to place the negative in a window with a sky exposure or to back it up with a ground glass and then to photograph the negative on the sensitive plate in the camera. Another and I think a surer and quicker process is to print the picture on the sensitive plate by contact and then develop it in the usual way. This is done by placing the negative in a printing frame and placing the sensitive side of the dry plate in contact

with it in a manner similar to that of printing on paper. The amount of exposure can be determined by experience only, as it varies in duration. If the plate is exposed at a distance of 18 inches from an ordinary 6 feet gas burner the variation will be from 20 to 35 seconds, according to the density of the negative.

The developer which I have found to be the most successful is made after the following formula:

No. 1.

Oxalate of potash	3 oz.
Water	10 oz.

No. 2.

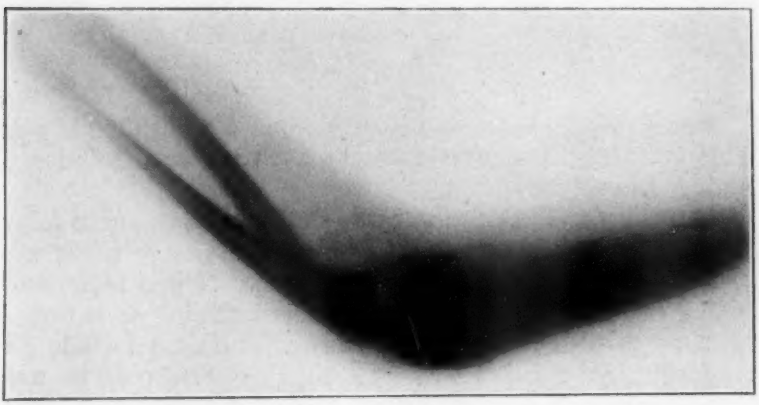
Iron protosulphate	3 oz.
Sulphuric acid	5 drops
Water	10 oz.

Use 3 parts No. 1 and 1 part No. 2. Should the plate develop too fast, add a few drops of a 10 per cent. solution of bromide of potassium.

In making up this developer care should be taken not to forget to add the sulphuric acid to the iron solution and to test it with litmus paper to see that it is strongly acid. If it is found upon mixing the two solutions that a brick-red precipitate is thrown down, the mixture must be thrown away, for if used it would ruin the plate. After being well washed the plate should be fixed in a solution composed of 1 pound of hyposulphite of soda and 1 gallon of water.

The use of very rapid plates with the flash-light has made it possible to picture the inside of mines and other very dark places; and they have proven a boon to astronomers, enabling them to picture the stars with great accuracy. A number of important astronomical discoveries have been made by the aid of photography. Many new stars have been discovered on the negatives that were unknown and invisible to the naked eye or the telescope. Wonderful and valuable pictures of eclipses of the sun, even to the extent of moving pictures, have been made. The transit of Venus has been photographed by its aid, and extra satellites to some of the planets have been discovered. As the earth is constantly in motion a carefully regulated clockwork is attached to the camera in order to keep the celestial object properly registered on the sensitive plate. Another of the interesting and educational features to which photography has been

applied are the now almost universal life-motion pictures. Some of them are of course made up to illustrate the subject shown, others showing the various industries and modes of life in this and foreign countries are natural and are not only interesting but also instructive to those whose means will not allow them to travel to distant lands. Another very interesting form of picture is the stereograph. This should properly be made with a pair of matched lenses. A division is placed in the camera, the two pictures taken on the same plate, and after being printed, they are cut apart and transposed, as the lenses reverse every-



X-ray photograph of forward dislocation of the elbow joint, rare form, on X-ray plate. By William B. Griggs, M.D., Children's Homeopathic Hospital, Philadelphia.

thing. This is the ideal form of picture, as it gives the effect of a picture seen with both eyes and everything stands out separately, whereas the photograph taken with one lens presents simply a flat surface. The proper manner in which to take a picture of a flash of lightning is to focus the camera during the day on some distant object, then during a thunder storm at night, if a spot is noticed where lightning-flashes occur quite frequently, place the camera so as to command a view of them, draw the slide out of the plate-holder, uncap the lens and trust to luck; for the capturing of a picture of a flash of lightning is really a matter of chance. Since the advent of balloons snapshot pictures have been used for topographical purposes and also during war times in making pictures of the enemy's position and the arrangement of fortifications and distribution of troops.

The latest and perhaps the most valuable and humanitarian use to which photography has been applied is in connection with the X-ray work. Here the two most comprehensive sciences, photography and electricity, go hand in hand for the benefit and instruction of humanity. By the use of these two great agents, deep-seated and obscure injuries have been pictured and a correct diagnosis made; bullets and other foreign bodies have been located and their removal made comparatively easy; and recently by the use of very rapid plates and large induction coils instaneous pictures showing the opening and closing of the valves of the heart have been made.

A REVIEW OF THE COAL-MINING INDUSTRY IN 1908.

DECREASE IN PRODUCTION.

From reports received by the United States Geological Survey it might be inferred that a most effective method of conserving the coal resources of the country is to develop a financial panic, for one result of the depression that followed the panic of October, 1907, appeared in decreased production of coal in the United States in 1908—a decrease of 15 to 20 per cent. as compared with the production of the preceding year.

In 1907 the production reached the unprecedented total of 480,363,424 short tons, of which 394,759,112 short tons were bituminous coal and lignite and 85,604,312 short tons were Pennsylvania anthracite. Letters received from State officials and others closely in touch with the coal-mining industry in the several States indicate that the bituminous coal production in 1908 was between 320,000,000 and 330,000,000 tons, or practically 70,000,000 tons less than in 1907.

The railroad shipments of anthracite in 1908 amounted to 64,237,076 long tons, or 71,945,525 short tons, as compared with 67,109,393 long tons, or 75,162,510 short tons, in 1907, indicating a decrease in the shipments of this product, which, except for the very smallest sizes, is now used almost exclusively for domestic purposes, of 2,872,317 long tons, or 3,217,005 short tons. This would indicate a decrease in the total production of anthracite of 3,580,000 short tons.

In the bituminous regions the effects of the panic were most seriously felt in the coking branch of the coal-mining industry, the Connellsville and the Lower Connellsville districts of Pennsylvania, the principal coke-producing centres, reporting a decrease in output amounting to nearly 50 per cent.

In Utah, where the smallest percentage of decrease in coal production is reported, namely, 6 per cent., the production of coke decreased about 60 per cent. The largest percentage of decrease is reported from the southwestern counties of Virginia, where the production in 1908 is estimated at 60 per cent. of that of 1907, all of the decrease being attributed directly to the effects of the panic. The next largest percentage or decrease was reported from Michigan, where the production is stated to have fallen off between 25 and 35 per cent., largely as the result of slackened demand in the manufacturing cities along the Lake front, a slackening due directly to the panic. In a few of the coal-mining States the protracted drought, which began in the summer and lasted well into the winter months, caused some embarrassment. In the Southwestern States—Kansas, Oklahoma, Arkansas, and Texas—the coal production was influenced less by the financial conditions

than by the competition of coal with fuel oil and natural gas, which has developed through the bringing in of the mid-continent and Louisiana fields, in addition to the already developed Beaumont district. A short cotton crop and a consequently lessened demand from ginning establishments, and a period of idleness from April 1 to June 15, pending a settlement of the wage scale, also adversely affected coal production in these States. Conditions in the later months of the year showed some improvement as compared with those in the first part, but at no time was there any excess of demand over supply. In the States of the Middle West operations were for a time suspended pending an adjustment of the wage agreement; elsewhere there were no serious troubles from strikes or lockouts. The labor supply was usually abundant, and transportation facilities were adequate for the requirements. It was the general impression at the close of the year that despite the prevailing tone of confidence a sudden return to prosperity was not to be expected, and that a return to normal conditions would be slow and gradual, and not in any sense a "boom."

SIGNIFICANCE OF DRAFTS IN STEAM-BOILER PRACTICE.

INVESTIGATIONS MADE BY THE GEOLOGICAL SURVEY.

Engineers of the United States Geological Survey express the opinion that it is possible to double or treble the capacity of a steaming plant without making any radical changes in furnaces or boilers, the increase requiring that about double or treble the quantities of air be put through the fuel beds and boilers. The basis for this opinion is set forth in a report by Walter T. Ray and Henry Kreisinger, which has just been published by the Survey as Bulletin 367.

This bulletin is announced as the first of a series of two or three on the significance of drafts in steam-boiler practice, the succeeding bulletins to follow the same lines but to be of more advanced character. The conclusions presented are tentative, and are the result of a study of one of the many problems growing out of the general plan of the Survey to increase the efficiency with which the coals of the country are being used. Greater efficiency requires better boiler and furnace design, and means a conservation of the fuel resources of the country.

The experiments reported in Bulletin 367 were undertaken with the object of clarifying ideas concerning the passage of air through fuel beds and boilers. Measured weights of air were passed through two beds of lead shot, in series, one of which remained always the same and represented a boiler, the other being varied as to size of shot and depth of bed and representing a fuel bed. Careful observations were made of the weight of air passing through the beds per minute, and all data were plotted on many charts, so as to permit the study of them from various points of view. A number of laws were deduced bearing on the relative amounts of power required to force air through fuel beds of various thicknesses, composed of various sizes of coal, and through boilers of various lengths and areas of gas passage.

To test the applicability of these laws, they were compared with the results of a number of practical experiments made at the St. Louis fuel-testing plant with boilers of the standard hand-fired Heine type, and the principles developed were also studied in connection with the results of certain locomotive tests made at the Norfolk testing plant of the Survey. These various tests and experiments are fully described.

As a result of these investigations the authors believe it may be possible to raise the rate of working the boiler heating surface to three or even four times its present value. Such an increase would undoubtedly mean new designs of grates, stokers, furnaces, and boilers, especially fitted for high rates of working. Fan equipments designed to supply three or four times as much air under several times the pressure would be provided with more efficient engines—an additional factor favoring high-capacity working.

THE ADDITION OF CARBON TO POWDERS WITH A NITROCELLULOSE AND NITROGLYCERIN BASE.

BY
CAPT. MONNI,

Translated from the *Moniteur Scientifique*, August, 1908,
BY
W. J. WILLIAMS, F.I.C.

THE results obtained by the use of the new nitro-powders in fire-arms have caused their rapid adoption by all armies and navies. Generally speaking, these powders consist either of a mixture of nitroglycerin and nitrocellulose or of nitrocellulose alone. It is needless to describe the properties of nitro-powders, for they are well known; it need be said only that from the economic and ballistic points of view, the addition of nitroglycerin offers advantages. But practical use has shown that these powders erode the bore of the pieces to such a degree that after a limited number of rounds they become useless. This harmful effect, which increases with the length of the weapon, is augmented in proportion to the quantity of nitroglycerin contained in the powder, and when it is taken into consideration that the products of the decomposition of these nitro-powders are all the same, the cause of this fact must be sought in the *temperature* of the decomposition of nitroglycerin, which is far higher than that of nitrocellulose. Moreover, the decomposition-products of nitroglycerin contain a great excess of carbon dioxide, which removes carbon from the metal. In view of this rapid attack, the Governments which have adopted powders with a nitroglycerin base, find themselves under the necessity of either abandoning their advantages or eliminating their drawbacks.

Italy chose the second method, and made a series of experiments to attain this end. For ten years I was detached to the Government factory of Fontana Léré and put in charge of the experiments conducted by distinguished chemists. I do not intend to detail all that was done, but I can show the grounds by which I arrived at the solution of the problem.

It is known that the Italian Army and Navy make considerable

use of balistite, which is a mixture of equal parts of nitroglycerin and nitrocellulose. This mixture is brought by a special method to a nitration of 12 per cent., which corresponds almost exactly to a 9-nitrocellulose. The respective molecular weights are

$$\text{Nitroglycerin, } C_3H_5(O.NO_2)_3 = 227$$
$$\text{Nitrocellulose, } C_{24}H_{31}O_{11}(O.NO_2)_9 = 1053$$

Balistite then is composed of one molecule of nitrocellulose and 4.64 molecules ($4.64 \times 227 = 1053$) of nitroglycerin.

The equation for the decomposition of nitroglycerin is well known: it is written

$$C_3H_5(ONO_2)_3 = 3CO_2 + 2.5H_2O + 1.5N_2 + 0.25O_2$$

It is different with nitrocellulose—its decomposition varies according to conditions and because it is composed of a mixture of products of higher or lower nitration. The following equation appears to be most in accordance with the facts

$$C_{24}H_{31}O_{11}(O.NO_2)_9 = 8CO_2 + 16CO + 6H_2O + 9.5H_2 + 4.5N_2$$

These decompositions being granted, then the products of the decomposition of balistite are

$$4.64C_3H_5(O.NO_2)_3 + C_{24}H_{31}O_{11}(O.NO_2)_9$$
$$= 21.9CO_2 + 16CO + 19.92H_2O + 7.18H_2 + 11.46N_2$$

or in round numbers

$$22CO_2 + 16CO + 20H_2O + 7H_2 + 11.5N_2$$

CALCULATION OF THE HEAT DISENGAGED AT CONSTANT VOLUME.

Heat of formation of 1 molecule CO_2	94	Calories
Heat of formation of 1 molecule CO	25.8	Calories
Heat of formation of 1 molecule H_2O	58.2	Calories
Heat of formation of 1 molecule $C_3H_5(O.NO_2)_3$	98	Calories
Heat of formation of 1 molecule $C_{24}H_{31}O_{11}(O.NO_2)_9$	609	Calories

Hence the result is

$$22 \times 94 + 16 \times 25.8 + 20 \times 58.2 - 4.64 \times 98 - 609 = 2581 \text{ Calories.}$$

If the gases are produced at constant pressure, then 2581 Calories are disengaged. To find the heat at constant volume,

there must be added to this figure the number of Calories equivalent to the work of the expansion of the gas.

L = the work.
$L = pv$ kilogrammetres.
$p = 10335$ kilogrammetres per square metre.
$v = (22+16+20+7+11.5)\ 22.321 = 1707.48$ litres.

$$L = \frac{10.335 \times 1707.48}{425} = 41.5 \text{ Calories.}$$

The sum $2581 + 41.5 = 2622.5$ Calories for a molecular weight equal to

$$22 \times 44 + 16 \times 28 + 20 \times 18 + 7 \times 2 + 11.5 \times 28 = 2112.$$

For each kilogramme of powder then, there are

$$\frac{2622.5}{2.112} = 1242 \text{ Calories} + \frac{1707.48}{2.112} = 808 \text{ litres of gas.}$$

Calculation of the Temperature of Combustion.—Let t be the temperature, q the quantity of heat, and c the specific heat between zero and $t°$; then

$$t = \frac{q}{c}$$

Mallard and Le Chatelier give the following values:

For CO_2 ..... $c = 6.26 + 0.0037\ t$ calories
For H_2O ..... $c = 5.61 + 0.0033\ t$ calories
For other gases ..... $c = 4.80 + 0.0006\ t$ calories

If these figures are applied to the quantities of gas given above, we get

For $22CO_2$ ..... $c_1 = 22 \times 6.26 + 22 \times 0.0037\ t$
For $20H_2O$ ..... $c_2 = 20 \times 5.61 + 20 \times 0.0033\ t$
For $16CO + 7H_2 + 11.5N_2$ ..... $c_3 = 34.5 \times 4.80 + 34.5 \times 0.0006\ t$

$$c = 415.51 + 0.1681\ t$$

Introducing these values into the equation

$$t = \frac{q}{c}$$

then

$$0.1681t^2 + 415.51t - 2622.5 = 0$$

$$t = \frac{-415.51 + \sqrt{415.51^2 + 4 \times 2622.5 \times 0.1681}}{2 \times 0.1681} = 2902° \text{ C.}$$

It remains then to find a means of diminishing the effect of this considerably high temperature. This effect is more intense the longer the gas remains in the metallic tube (bore); that is, the greater the diameter and length.

As a long series of trials has shown, the simplest method is to add a certain quantity of carbon to the balistite, which, at the temperature under consideration, transforms all the carbon dioxide into twice its volume of carbon monoxide. Theoretically, $22 \times 12 = 264$ Gm. of carbon are required to reduce the 22 molecules of carbon dioxide (CO_2), formed on firing 2112 Gm. of balistite, into carbon monoxide (CO). Then the explosion produces

(α) $60CO + 20H_2O + 7H_2 + 11.5N_2$, molecular weight = 2376

If it be admitted that the oxygen of the water can also be combined with carbon, then 20 atoms more of carbon can be used and the gases become

(β) $80CO + 27H_2 + 11.5N_2$, molecular weight = 2616

If the case is studied in detail, the calculation of the explosion is

FOR EQUATION α

Heat disengaged at constant volume for 1 kg. explosive.....716 Calories
Volume of gas produced.....925 litres
Temperature of explosion.....2278°

FOR EQUATION β

Heat disengaged at constant volume for 1 kg. explosive.....407 Calories
Volume of gas.....1011 litres
Temperature of explosion.....1565°

Does this reduction of temperature actually take place in practice? I will show by the results of experiments how closely these theoretical forecasts are verified.

But it must be borne in mind that equal quantities of balistite and of these carbonated powders do not possess the same explosive force. They give

For balistite ....$f_1 = 808\left(1 + \frac{2902}{273}\right) = 9397$ atmospheres per kg.

For powder α....$f_2 = 925\left(1 + \frac{2278}{273}\right) = 8639$ atmospheres per kg.

For powder β .... $f_3 = 1011\left(1+\frac{1565}{273}\right) = 6804$ atmospheres per kg.

For a content of carbon increasing up to 19 per cent. (as in formula β) the volume of the gaseous products formed increases, but does not compensate for the diminution of temperature. To obtain the same explosive force the charge of powder must be augmented.

A series of experiments proved this was the case. It is necessary to calculate the charges required to obtain the same initial velocity of the projectile at the muzzle of the gun with balistite containing variable amounts of carbon. The results are

Percentage of carbon in the balistite	Charge	Percentage of carbon in the balistite	Charge
0	100	10	116.5
2.5	103	11	118
5	109	13	122
7.5	112	15	123
8	113	19	137
9	115		

The data were very difficult to obtain for percentages above 15.

Certain calorimetric determinations were made which are only valuable for comparison. Thus it was found

Percentage of carbon in the balistite	Charge	Rise of temperature	Percentage of carbon in the balistite	Charge	Rise of temperature
0	100	45°	10	116.5	35.5°
2.5	103	44°	11	118	34.2°
5.0	109	42.6°	13	122	33°
7.5	112	39°	(1) 15	123	30.3°
8	113	37.6°	(2) 19	137	31°
9	115	36.3°			

It is obvious that the values found for the rise of temperature decrease progressively and in a very notable degree in proportion as the temperature (sic; charge) increases.

It is true that neither the charge nor the rise of temperature follows the percentage of carbon exactly; but that is because in

manufacturing on the small scale, it is impossible to avoid all the defects which influence the ballistic properties of the explosive. Moreover, the last two results (1 and 2) do not really contradict each other; if the temperatures are considered in relation to the weights of the explosive which would contain the same quantity of nitrated products, the temperature for 2 would be 29.5°, lower than that found for 1.

In proof of the fact that the carbon actually reacts, as in the equations given, it is well to emphasize the fact that during the explosion there is neither smoke nor residue produced. Hence the inference is strong that carbon determines the quantity and the nature of the products of explosion.

Must it not be concluded from these results that balistite, and all powders which produce a large proportion of carbon dioxide, act upon the steel of the muzzle of the gun by removing its carbon?

To answer this question, an apparatus was constructed, analogous to that described by Vieille (Mém. des poudres et salpêtres, vol. xi) to measure the erosion. Vieille, in his experiments, always used the same weight of powder. But in this way an exact expression of the damage done by different powders cannot be obtained. It is preferable, and more logical, to experiment with such quantities of powder as give the same ballistic effect, while keeping the other factors which may influence the result as constant as possible. Hence the powders are granulated so that the duration of combustion shall be the same for all. The following results were obtained:

	Atmospheres	Erosion
Ordinary balistite	3413	0.3038 Gm.
Balistite with 11.28% carbon	3768	0.3048 Gm.

Vieille found that with the same powder the erosion is proportional to the pressure developed in the gun:

	Atmospheres	Erosion
Ordinary balistite	2162	.3038 Gm.
Balistite with 11.28% carbon	2366	0.1461 Gm.
Ordinary balistite	2313	0.3874 Gm.
Balistite with 8.00% carbon	2323	0.2108 Gm.
Balistite with 11.28% carbon	2543	0.1730 Gm.

It is seen, that in spite of a heavier charge of carbonated products and in spite of higher pressure, the erosion is less.

The following comparative experiments were made:

	Atmospheres	Erosion
Balistite with 8% carbon	1,050	0.0041 Gm.
Balistite with 11.28% carbon	911	0.0031 Gm.
Black powder	1,077	0.0118 Gm.
Rottenciler powder	1,020	0.0100 Gm.
Smokeless powder	1,438	0.0110 Gm.

These results need no comment. But this point may be insisted on; if, as Vieille assures us, it is admitted that erosion is produced in the same manner in the apparatus for measuring the erosion as it is in fire-arms, the results prove that carbonated balistite is the least erosive of the explosives.

But, it may be asked, what guarantees can be offered for carbonated balistite from the chemical, physical, and ballistic points of view? The only answer is that these are the same as for ordinary balistite, *i.e.*, it is easily and conveniently manufactured, it offers considerable resistance to variations of temperature and humidity, and its ballistic effect is constant; its combustion is a little slower. Both in economy and in practical results, it corresponds to what was sought.

My official position prevents my going into detail concerning the experiments made to determine the best proportion of the components, the general properties of the powder, and the method of making it suitable for different weapons. The Italian patent is open to the public and any one can study the process.

An interesting question, from the practical point of view, is the use of carbonated balistite as a sporting powder. In fact its production is one-half more economical than that of the commercial powders made for this purpose, and there is no fear that the guns will be deteriorated.

Those who have used balistite as a sporting powder and have not obtained the expected results, may claim that it would have been just the same notwithstanding the addition of carbon. But it is easy to refute this objection. Once its chief fault, the erosive property, is eliminated, the rest is only a comparatively simple question of granulating the powder.

Carbonated balistite can be sold at a price as advantageous for the merchant as for the manufacturer. It is sufficient to say that the cost of production should not exceed 5 fr. 50 ($1.10), and that the charge is about one-third of the equivalent charge of black powder.

FRANKLIN INSTITUTE

(Proceedings of the Annual Meeting held Wednesday, January 20, 1909.)

HALL OF THE FRANKLIN INSTITUTE.

PHILADELPHIA, January 20, 1909.

President Walton Clark in the Chair.

Present 45 members and visitors. Additions to membership since last report 5.

The Annual Report of the Board of Managers, with appendices embracing the annual reports of the several committees of the Board and of the Institute, was presented.

The Tellers of the annual election reported the election of all the candidates nominated at the stated meeting of Wednesday, December 16, 1908.

The President then introduced Mr. Franklin J. Truby, of Chicago, who read a paper on "Automatic Telephony." The speaker described the details of the system by means of lantern slides and a working exhibit of an Automatic Telephone Exchange. After a brief discussion the subject was referred to the Committee on Science and the Arts for investigation and report and the speaker of the evening was tendered a vote of thanks.

Adjourned.

JAMES CHRISTIE,
Secretary.

REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1908, WITH APPENDICES EMBRACING THE ANNUAL REPORTS OF THE VARIOUS COMMITTEES AND SECTIONS.

To the Members of the Franklin Institute:

The Board of Managers herewith transmits the reports of its Committees on Instruction, Elections and Resignations, Stocks and Finance, Publications, and Sectional Arrangements, and of the Franklin Fund and Building Committee. With the exception of the last named committee, these reports cover a period of nine months only, terminating September 30, which is now the end of the Institute's year.

In connection with the report of the Committee on Instruction, should be noted the steps taken in the spring toward the formation of the Alumni Association of the Franklin Institute. As the actual organization did not occur until after October 1, no further mention of it will be made at this

time than to express the hope that it may be of great assistance in aiding the development of our schools, and to state that steps should be taken to utilize the Alumni in the work of the Institute.

The financial condition of the Institute has been greatly improved during the year, and all obligations are being promptly met.

The most important event of the year is shown in the report of the Franklin Fund and Building Committee, to wit: the securing of the Franklin Fund from the Board of City Trusts. This fund, with the subscriptions received by the Committee, forms the Franklin Institute Building Fund, which on December 31 amounted to $322,779.46, and is held by the Board of City Trusts for the use of the Institute in erecting its new building. If to this is added the amount of money still owing the Committee and the value of our present building, about $400,000 is shown as available for building purposes. It is hoped that during the coming year an appreciable addition to this sum can be effected, and to this end the aid of every member of the Institute is solicited. As the Committee states, the delay in fixing the exact line of the Boulevard has prevented a definite selection of a site for our new building. When this obstacle has been removed, every endeavor will be made by the Committee toward the speedy procuring of the new home that will enable the Institute to carry forward under favorable auspices the varied activities for which it has been so well known in the past.

The resignation of Dr. Wahl as Secretary has left a vacancy that will be hard to fill. The Institute has been very fortunate in securing the services of Mr. Christie, pending the selection of a permanent Secretary. The following resolution has been adopted by the Board of Managers to mark their appreciation of Dr. Wahl's career of service and accomplishment:

Resolved, That the resignation of Dr. William H. Wahl as Secretary of the Franklin Institute, having brought a termination to the faithful and unremitting service which he has rendered in that capacity through more than a quarter century past, the Board of Managers of the Institute enter upon its minutes this acknowledgment of Dr. Wahl's successful efforts in the furtherance of the Institute's work and this expression of regret that the condition of his health has appeared to necessitate at least a temporary cessation from his labors.

In the organization of the scientific sections of the Institute, in the promotion of its lecture courses, in the enlargement of its schools, and in the editorial direction of its Journal and other publications, Dr. Wahl has performed a distinguished part in the activities of the Franklin Institute, and left a lasting impress on its history.

As a mark of appreciation of Dr. Wahl's services as Secretary and as a member of this Board, this minute is ordered to be suitably engrossed for presentation to Dr. Wahl and to be published in the Journal of the Franklin Institute.

During the year, the Board has lost by death Mr. Jawood Lukens, who has served since 1903, and Mr. Stephen Greene, whose service dates from 1898. Suitable minutes will be prepared to form part of the records of the Board. The Board has also lost by resignation Mr. Thomas P. Conard,

who became a Manager in 1896. The Board desires here to bear testimony to the work done by these men, both as members of the Institute and of the Board, in furthering the interests of the Institute.

For the Board of Managers,

WALTON CLARK,
President.

PHILADELPHIA, January 11, 1909.

REPORT OF THE COMMITTEE ON INSTRUCTION FOR THE YEAR 1908.

To the Board of Managers:

The plan of conducting a course of popular science lectures in the Building of the Young Men's Christian Association was temporarily abandoned during the year. In place of the regular course of about twelve lectures, only one-half that number was announced; three were given during the fall of 1907 and three during the spring of 1908. These lectures were delivered in the Institute's hall, and, while the attendance was quite satisfactory, arrangements have been made to continue these courses in the new hall of the Young Men's Christian Association during the present season. As in previous years the speakers received no compensation.

The schools of the Institute have been fairly well atended, and the business depression of the year has not had any great effect on the enrollment. A change in the management of the School of Machine Design has been effected, and the founder of the school, Mr. Lucien E. Picolet, has been secured and will take charge as Director.

The attendance at the spring term (1908) of the schools was as follows:

Drawing School	97
School of Machine Design	38
School of Naval Architecture	7
Total	142

Respectfully submitted,

ALFRED RIGLING,
Acting Chairman.

PHILADELPHIA, PA., January 13, 1909.

REPORT OF THE COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS FOR THE YEAR 1908.

To the Board of Managers:

The Committee on Elections and Resignations beg leave to state, that the efforts of the Board have resulted in securing 28 resident members, 11 non-resident members, and 2 life members.

During the same period resignations were presented and accepted by the Board of 18 members, making a net gain of 23 members.

Respectfully submitted,

ALEXANDER KRUMBHAAR,
Chairman.

PHILADELPHIA, PA., January 13, 1909.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE FOR THE YEAR 1908.

To the Board of Managers:

FINANCIAL STATEMENT.

January 1 to September 30, 1908.

Property and Funds—			
Building and Land, 13–17 S. 7th St.		$44,000.00	
Library		100,000.00	
Apparatus, Collections, and Models		5,022.49	
Investments not held for Trust Funds		2,100.00	$151,122.49
Funds held by Board of Trustees—	Principal.	Unexpended Income.	
General Endowment Fund	$51,350.50	$220.00	
Building Fund	2,685.67	65.60	
E. M. Graff Fund	14,092.12	23.48	
Journal Endowment Fund	138.00		
M. Carey Lea Fund	2,000.00	150.66 (credit)	
Edward Longstreth Medal Fund	1,000.00	288.76	
J. T. Morris Memorial Fund	5,056.25	542.22	
Special Endowment Fund	44.51	657.64	
Potts Library Fund	952.50	14.08	
Potts Medal Fund	1,000.00	26.33	
Funds held by Board of Managers—			
B. H. Bartol Trust Fund	1,000.00	77.50	
Boyden Premium	1,000.00	370.71	
H. W. Jayne Library Fund	500.00		
B. H. Moore Memorial Fund	15,000.00		
New Building Fund	5,360.08*	100.00	
New Building Endowment Fund	115.00		
Endowment Fund, Memorial Library	1,000.00†	26.03	
Funds held by Board of City Trusts—			
Franklin Fund	149,630.74		
Elliott Cresson Fund	1,000.00	3,433.43	
Total Funds	$252,925.37	$5,695.12	$258,620.49
Grand Total			$409,742.98

* $4863.50 of principal merged with general funds of the Institute.
† Entire principal and income merged with general funds of the Institute.

LIABILITIES.

Certificates of Stock—			
First Class	$36,140.00		
Second Class	1,130.00	$37,270.00	
Mortgage on Institute Building (held by Trustees as investment for Funds)		5,075.00	$42,345.00
Bills Payable—			
Girard National Bank		$3,000.00	
Western Saving Fund Society (secured by collateral)		2,100.00	
Franklin Fund and Building Committee		10,000.00	
Loans contracted in 1902 to meet deficit, notes for which are still held by original payees		2,150.00	
Loans contracted in 1902 and 1903 to meet deficit, the notes for which are now held by Building Committee		3,150.00	20,400.00
Life Memberships (owed to Board of Trustees)			3,835.00
Accounts Payable			1,433.83
Unearned Income—			
Advance Dues		$143.32	
Advance Tuition		674.50	817.82
Grand Total			$68,831.65

INCOME AND EXPENSES.

Applicable to the Nine Months ending September 30.

INCOME.

Dues	$6,727.44
Initiation Fees	55.00
General Endowment Fund	1,514.45
Estate of Robert Wright	1,000.00
Donations	1,000.00
Income from Investments	70.50
Miscellaneous	12.69
Membership Badges	7.00
Instruction Tuition Fees	1,124.71
Library, Books, and Periodicals	* 1,604.72
Publications: Subscriptions and Sales	1,171.13
Advertising	1,725.73
Total	$16,013.37

* Due to crediting this account with $2806.93, unexpended income of Bloomfield Moore Memorial Fund.

EXPENSES.

Building: Wages	$660.65	
Repairs and Maintenance	569.74	
Heat, Light, and Power	472.81	
Taxes, Water Rent, and Insurance	428.66	
Miscellaneous Supplies and Expenses	408.02	$2,539.88
Elections and Resignations		167.20
Instruction		934.58
Library: Salaries	1,235.25	
Books and Periodicals		
Miscellaneous Expense	708.23	1,943.48
Meetings: Printing	103.95	
Miscellaneous Expense	158.67	262.62
Office and General: Salaries	2,694.59	
Office Expense	531.93	
General Expense	302.56	3,529.08
Publications: Printing	2,427.03	
Engraving	389.76	
Miscellaneous	489.60	3,306.39
Interest and Discount		151.07
Science and Arts		136.37
Sections		181.31
Interest paid John T. Kille on donation to General Endowment Fund		200.00
Total		$13,351.98
Net Income		2,661.39

As is seen by the financial statement above, the fiscal year of the Institute now ends on September 30, thus becoming coterminous with the membership year. Therefore, the statement embraces a period of nine months only.

During this period the Institute received funds as follows: The General Endowment Fund has been increased $400 through the receipt of two life membership fees. Through the will of Elizabeth M. Graff, a sum of $14,092.12 was given to be used to perpetuate "the memory of Frederic Graff in a building or some other substantial manner." Through the will of Howard N. Potts, the sum of $952.50 was given as a library fund, the interest to be used in the purchase of books, and the sum of $1000 was given, the interest to be used for a gold medal to be awarded for distinguished work in science or the mechanic arts. Through the Franklin Fund and Building Committee, the sum of $149,630.74 has been turned over to the Board of City Trusts to form the beginning of the Franklin Fund, which will be devoted to a new Institute building. Through this Committee also, $115 has been received, forming the nucleus of a New Building Endowment Fund.

By a resolution of the Board of Managers, the Building Fund and Special Endowment Fund, held by the Board of Trustees, and the New Building Fund, held by the Board of Managers, were assigned to the Franklin Fund and Building Committee, to be merged in the Franklin Fund, and a portion of the $149,630.74, above mentioned, consisted of securities belonging to these funds. Ultimately these funds will be entirely merged in the Franklin Fund.

The amount owed by the Institute is great, but it is believed that in future current receipts will be in excess of expenses, and each year will show a reduction in this indebtedness. For 1908. only $5,100 of the Bills Payable drew interest. In 1909, $15,100 will draw interest.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, PA., January 11, 1909.

REPORT OF THE COMMITTEE ON PUBLICATIONS FOR THE YEAR 1908.

To the Board of Managers:

The Committee respectfully reports that it has secured necessary copy to enable the continuation of the publication of the Journal, and maintain the standard of the same.

The contract for printing the Journal has been continued to this time as of last year. The Committee also beg leave to state, that they have been able to secure some new advertisements, and have further prospects of securing still more.

Respectfully submitted,

HARRY W. JAYNE,
Chairman.

PHILADELPHIA, PA., January 13, 1909.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS FOR THE YEAR 1908.

To the Board of Managers:

During the past nine months there were held 17 meetings of the Sections, all of which were devoted to the presentation of papers on scientific and technical subjects. The greater number of papers and a great deal of the material printed in the Journal is derived from this source.

The work of the Sections was divided up as follows:

Section of Physics and Chemistry.....	2	meetings.
Electrical Section	4	"
Mining and Metallurgical Section	5	"
Mechanical and Engineering Section.....	3	"
Photographic Section	3	"
Total	17	"

Your committee wishes to express its appreciation of the services of the lecturers, professors and the Section officials in assisting to make these weekly meetings attractive and successful and regret that many of the discourses are not as well attended as they should be.

Respectfully submitted,

JAMES CHRISTIE,
Chairman.

PHILADELPHIA, PA., January 13, 1909.

REPORT OF THE CURATORS FOR THE YEAR 1908.

To the Board of Managers:

The Curators beg to report that during the past year the Electrical wiring of the Building has been completely renovated. The condition of this work, which was done from time to time and without critical inspection, was objected to by the Underwriters Association. This work incurred considerable expense but is now entirely satisfactory to the Underwriters.

The roof, which has always been a source of some trouble, has been repaired and repainted thoroughly and there is some additional painting to be done which will be completed in the spring; we have the material for it on hand.

The stove in the lecture room has been removed and steam pipes replaced instead for heating purposes and other radiators have been repaired.

A few new tools have been secured to facilitate repairs and much of the inflammable material heretofore stored in the basement has been removed. The basement is gradually being put into better shape.

Respectfully submitted,

CHAS. E. RONALDSON,
JAMES CHRISTIE,
Curators.

PHILADELPHIA, PA., January 18, 1909.

REPORT OF THE FRANKLIN FUND AND BUILDING COMMITTEE FOR THE YEAR 1908.

To the Board of Managers:

Your Committee begs leave to report that the agreement between the Franklin Institute and the City of Philadelphia, Trustee, has been completed by the payment on Dec. 31, 1908, of the sum of $50,000.

During the year the two properties at the S. E. Cor. of 16th & Arch Sts. have been purchased and transferred to the City of Philadelphia, Trustee for the Franklin Institute, and in addition to this amount $100,000 and more has been transferred, completing the agreement with the Board of Minor City Trusts whereby the sum of $125,000 and upwards was set aside for the use of the Institute in erecting a new building.

The account of the Treasurer of the Franklin Fund and Building Committee, Dec. 31, 1908, shows a total amount of subscriptions of $200,572.75, and amount paid on account of subscriptions to Dec. 31, 1908, $189,012.75, leaving a balance of unpaid subscriptions of $11,560.

A number of the subscriptions forming this balance are made up of notes of the Institute transferred from subscribers to the Franklin Fund and Building Committee and held by the said Committee.

The account of the City of Philadelphia, Trustee, has been submitted, and the Franklin Institute Building Fund is credited with $322,779.46, including the money transferred to the Trustees by the Institute, the amount of the Franklin Fund and the accumulated interest to date.

Your Committee has not as yet selected an architect, nor has it undertaken to make any plans in regard to the selection of a site upon which to erect the new building. The Boulevard line extending from the City Hall to Fairmount Park has not as yet been settled. The City Park Association has presented a plan changing the line considerably so as to bring the City Hall tower in a line with the centre of the Boulevard.

The new line cuts through the property owned by the Institute and the property adjoining, upon which we have an option, to such an extent that if this line is adopted no adequate building can be erected on the S. E. Cor. of 16th and Arch Sts. If the plan is eventually adopted other nearby sites will have to be considered, and as soon as the Boulevard line is finally fixed upon your Committee will act accordingly.

Respectfully submitted,

HENRY HOWSON,
Chairman.

PHILADELPHIA, PA., January 13, 1909.

REPORT OF THE LIBRARY COMMITTEE FOR THE YEAR 1908.

To the President and Members of the Franklin Institute:

The Committee on Library respectfully submits the following report:

The additions to the Library during the nine months ending September 30, 1908, comprised 2301 titles.

The new acquisitions include:

1010 bound volumes,
242 unbound volumes,
1042 pamphlets,
3 photographs,
2 engravings,
1 manuscript,
1 drawing.

These accretions were derived from the following sources:

40 through the Bloomfield Moore Fund,
12 through the Memorial Library Fund,
8 through the M. Carey Lea Fund,
38 from the general Library appropriations,
473 through the binding of periodicals,
40 through the Journal of the Institute,
3 through the exchange account,

and the remainder through deposits from the Federal and State Governments, through contributions from societies and institutions at home and abroad and through gifts from individual donors. Especially notable contributions were received from:

Drs. Wm. H. Greene, Samuel C. Hooker, Edwin J. Houston, Charles S. Jack, Harry F. Keller, Henry Leffmann, and Paul J. Sartain; Mmes. M. C. G. Canby, Samuel C. Hooker, L. K. Perot, and M. Russell Thayer, and the Messrs. H. M. B. Bary, John E. Carter, George S. Cullen, Carl Hering, E. Hunn, Strickland L. Kneass, Louis E. Levy, Charles S. Linch, T. C. McCollom, Edward S. Miles, and Lewis S. Ware, and from The Royal Technical High School of Karlsruhe; the New York State Library, The Pennsylvania State Library, from the Librarian of the University of Texas, and from the United States Government.

The present contents of the library are as follows:

62827 volumes (bound and unbound),
45955 pamphlets,
2911 maps and charts,
782 drawings and designs,
1305 photographs,
192 newspaper clippings,
34 manuscripts.

A total of 114006 titles.

The following number of duplicates are on the shelves:

571 bound volumes,
368 unbound volumes, and
165 numbers of periodicals.

BINDING.

Binding and re-binding were effected during the past year as follows:

496 volumes of completed serials,
59 paper-bound books,
4 re-bindings.

PAMPHLETS.

The condition of the pamphlet collection remains unchanged. The pamphlets are stored on the first floor of the building, where they are properly preserved though unavailable through lack of classification. Many of these pamphlets are of unquestionable value, and it would be advisable to start the work of cataloguing as soon as possible, as it will take several years to complete it.

EVENING ATTENDANCE.

The Library was open on thirty (30) evenings during the past nine months with a total attendance of 170 visitors.

The number of those using the reading room was greatest in January, followed by the month of April; the smallest attendance was during the month of February.

UNION LIST.

The Index to periodicals in Libraries, in and around Philadelphia, was issued during the year, and we received the 25 copies which the Institute subscribed for. The excess copies are offered for sale and can be had by applying to the Librarian.

PUBLIC DOCUMENTS.

Arrangements are being made to dispose of all the Public Documents which are now being received and for which we have no use, to the Free Library of Philadelphia.

These books comprise a large proportion of the documents which we receive, and occupy a very large portion of our limited space of shelving.

The elimination of this material will enable the Library to retain a complete set of the scientific documents to which we can refer when necessary, and this will give us shelf-room for a great many volumes.

We again call attention to the fact that the care of the books is growing more serious from year to year. The stack which was built ten years ago is filled, and it is difficult to know what to do with the new books which are being constantly received.

Respectfully submitted,

CHAS. E. RONALDSON,
Chairman.

PHILADELPHIA, PA., January 11, 1909.

REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1908.

To the President and Members of the Franklin Institute:

The Committee on Meetings has arranged the program of the stated meetings of the Institute as heretofore. It is the intention of the Committee to continue to make the monthly meetings specially interesting for the membership at large and for the general public.

A number of new inventions were shown during the past nine months, and several articles of permanent value were secured for the Institute JOURNAL.

The small attendance at these meetings is still the rule, and it is undoubtedly due, in a great measure, to the location of the Institute building.

Respectfully submitted,

WASHINGTON JONES,
Chairman.

PHILADELPHIA, PA., January 13, 1909.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1908.

To the President and Members of the Franklin Institute:

The Committee on Science and the Arts has the honor to submit the following account of its operations during the nine months, ending September 30, 1908. The total number of cases on the Record-book on September 30, 1908, was 71, of which 45 were carried over from previous years; 26 were new cases added during the year; the number of cases disposed of during 1908 was 12; the number of cases pending on September 30, 1908, was 59. In 4 cases the Elliott Cresson Medal was awarded; 3 received the award of the John Scott Legacy Medal and Premium; 1 received the Edward Longstreth Medal of Merit, and 1 received the Certificate of Merit. Two reports were made advisory and 1 application was dismissed. There were 3 protested cases, which have been included among those pending. The list of awards is appended hereto.

A Sub-Committee on Reorganization was appointed early in the year to recommend methods to increase the efficiency of the Committee's work.

This Sub-Committee has not yet filed its final report, but it has reported progress, to the effect that it has held frequent meetings during the year, has practically completed its work, and will soon report recommending methods, and amendments to the By-laws of the Institute, and to the Regulations of the Committee, to put them into effect, which in the opinion of the Sub-Committee will, if adopted, increase the efficiency and raise the standard of the work of the Committee.

While, therefore, the full report and result of the labors of this Sub-Committee cannot be included in this report, yet its work must be considered an important part of the activities of the Committee for the year, placing it harmoniously in line with the efforts being made under the leadership of the present able President to improve the work of the Institute as a whole, and make it continue worthy the high position it has always held.

Respectfully submitted,

JAS. S. ROGERS,
Chairman.

PHILADELPHIA, PA., January 6, 1909.

APPENDIX.

DETAILS OF THE COMMITTEE'S WORK DURING THE NINE MONTHS ENDING SEPTEMBER 30, 1908.

Number of cases pending on December 31, 1907	45	
Number of cases proposed January 1–September 30, 1908	26	
Total number of cases before the Committee at time of report,		71
Total number of cases finally disposed of to September 30, 1908,	12	
Total number of cases pending September 30, 1908	59	
		71

The 12 cases disposed of were determined as follows:

Award of the Elliott Cresson Medal	4
Award of the John Scott Legacy Medal and Premium	3
Award of the Edward Longstreth Medal of Merit	1
Award of the Certificate of Merit	1
Reports made advisory	2
Applications dismissed	1
Total	12

DETAILS OF AWARDS, ETC.

AWARDS OF THE ELLIOTT CRESSON MEDAL.

2397. Henry A. Wise Wood, for his "Autoplate Machine."

2416. Anatole Mallet, for his "Articulated Compound Locomotive."

2424. Romeyn B. Hough, for his "Contributions and Characteristics and Uses of American Woods."

2427. Patrick B. Delany, for his "Telepost—New System of Automatic Telegraphy."

AWARDS OF THE JOHN SCOTT LEGACY PREMIUM AND MEDAL.

2395. Mathias Pfatischer, for his "Variable Speed Motor."

2417. William I. Ballentine, for his "Process of Testing the Hardness and Density of Metals and other Materials."

2422. Homer A. Herr, for his "Improvement in Presses for the Extraction of Liquids."

AWARDS OF THE EDWARD LONGSTRETH MEDAL.

2425. Dr. Allerton S. Cushman, for his "Researches on the Corrosion of Iron and Steel."

AWARDS OF THE CERTIFICATE OF MERIT.

2369. General Electric Company, for their "Magnetite Lamp."

REPORTS MADE ADVISORY.

2410,
2418.

APPLICATION DISMISSED.

2414.

FRANKLIN INSTITUTE

PROBLEMS IN THE STRENGTH OF MATERIALS SOLVED BY ELEMENTARY MATHEMATICS IN THE NIGHT-COURSES OF THE INSTITUTE.

BY
LUCIEN E. PICOLET,
Director, School of Machine Design.

MODERN text-books on the strength of materials planned to meet the requirements of technical schools, nearly uniformly adhere to a method of treatment in which the higher mathematics taught in an undergraduate course is, very properly, employed to the exclusion of other methods. Probably, for that reason, it is generally assumed that a knowledge of the higher mathematics is indispensable to the satisfactory study of the subject.

There is a large class who are called upon to deal with the relatively more simple problems in structural design, who have not the opportunity of securing the necessary mathematical preparation for a study of the best available text-books. This class the Institute aims to aid by its night-courses in machine design.

Courses in algebra, geometry, and plane trigonometry are provided and with this preparation it has been found possible to solve many of the problems in mechanics and the strength of materials usually treated by the methods of the differential calculus.

Most of these problems belong to the classes involving investigation for maximum and minimum and the process of integration.

The substitutes employed are known and tried devices and, within their scope, appear to have been utilized for comparatively few special cases. How extensively the ground can be covered may be judged from the sequel.

MAXIMA AND MINIMA.

When the relation between two variable quantities, a and x, is expressible in the form of the quadratic

$$ax^2+bx+c=0,$$

the condition for maximum or minimum is that the quantity under the radical in the solution for x,

$$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a},$$

shall be zero.

The greatest possible value of a is that which makes $4\ ac=b^2$. For any greater value the expression becomes imaginary and inadmissible when real values only are considered.

The minimum occurs when $4\ ac$ consists of two or more terms and decreasing the one sought increases the value of $4\ ac$.

Both maximum and minimum occur when $b^2-4ac=0$ forms a quadratic in terms of the variable.

The various phases and limitations of the method are fully treated in Williamson's Differential Calculus.

INTEGRATION.

The simple integrals of the form

$$\int dx,\ \int xdx,\ \int x^2dx \text{ and } \int x^3dx$$

cover the solution of nearly all the formulas given in the several hand-books issued by structural steel manufacturers. These can be readily evaluated by a purely algebraic method in a manner perfectly intelligible to students conversant with the elements of algebra or by a geometric method which has been in considerable use for the elementary treatment of special cases.*

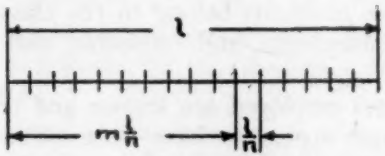


FIG. 1.

Fig. 1 is a graphic representation of the summation of these integrals between the limits of l and o.

* Strength of Materials—De Volsen Wood. Mechanics Applied to Engineering—Goodman.

The length l is divided into n equal parts which may be indefinitely diminished by indefinitely increasing the value of n. The quantity

$$\frac{l}{n} \quad \text{corresponds to} \quad \triangle x$$

and

$$m\frac{l}{n} \quad \text{corresponds to the variable } x.$$

The simple integral

$$\int_o^l dx$$

may be expressed by

$$\sum_o^l \frac{l}{n} \quad \text{or} \quad \frac{l}{n}$$

taken n times which equals l regardless of the magnitude of n, a result evident enough from inspection.

The evaluation of the remaining expressions is not so evident and requires demonstration.

The expression

$$\int_o^l x dx$$

may be written by the notation of Fig. 1

$$\sum_o^l \left(m\frac{l}{n}\right)\frac{l}{n}$$

when m is successively 1, 2 3 . . . n to n terms. The sum of these products is accordingly

$$\sum_o^l \left(m\frac{l}{n}\right)\frac{l}{n} = \left(\frac{l}{n}\right)\frac{l}{n} + \left(2\frac{l}{n}\right)\frac{l}{n} + \left(3\frac{l}{n}\right)\frac{l}{n} + \ldots . + \left(n\frac{l}{n}\right)\frac{l}{n}$$

This reduces at once to the simple arithmetic series,

$$\sum_o^l \left(m\frac{l}{n}\right)\frac{l}{n} = \frac{l^2}{n^2}[1+2+3+4+ \ldots . n]$$

The sum of an arithmetic series is

$$S_1 = \frac{n}{2}[2a+(n-1)d]$$

and when $a = 1$ and $d = 1$

$$S_1 = \frac{n(n+1)}{2}$$

the sum of n terms of the series in brackets. Inserting this value of the sum for the series,

$$\sum_{o}^{l}\left(m\frac{l}{n}\right)\frac{l}{n} = \frac{l^2}{n^2}\frac{n(n-1)}{2} = \frac{l^2}{2}$$

as n increases without limit.

In evaluating

$$\int_{o}^{l} x^2 dx$$

a similar treatment leads to the series,

$$\sum_{o}^{l}\left(m\frac{l}{n}\right)^2\frac{l}{n} = \frac{l^3}{n^3}[1^2+2^2+3^2+ \ldots\ldots +n^2]$$

To find an expression for the sum of this series the following artifice * may be employed to express it in terms of an arithmetic series,

$$\begin{aligned}
n^3-(n-1)^3 &= 3n^2-3n+1\\
(n-1)^3-(n-2)^3 &= 3(n-1)^2-3(n-1)+1\\
(n-2)^3-(n-3)^3 &= 3(n-2)^2-3(n-2)+1\\
&\ldots\ldots\ldots\ldots\ldots\ldots\\
&\ldots\ldots\ldots\ldots\ldots\ldots\\
(3)^3-(2)^3 &= 3(3)^2-3(3)+1\\
(2)^3-(1)^3 &= 3(2)^2-3(2)+1\\
(1)^3-(0)^3 &= 3(1)^2-3(1)+1
\end{aligned}$$

Adding the corresponding members, all but the first term of the left member of the first equation cancel. The sum of the first terms of the right members, S_2, is the sum of the series required, taken 3 times; the sum of the second terms is

$$3S_1 = 3\frac{n(n-1)}{2}$$

and the sum of the last terms is n and

$$n^3 = 3S_2 - 3\frac{n}{2}(n+1) + n$$

* Hall and Knight's Higher Algebra.

Solving for S_2

$$S_2=\frac{n(n+1)(2n+1)}{6}$$

and

$$\sum_o^l\left(m\frac{l}{n}\right)^2\frac{l}{n}=\frac{l^3}{n^3}\frac{n(n+1)(2n+1)}{6}$$

As n is indefinitely increased

$$\sum_o^l\left(m\frac{l}{n}\right)^2\frac{l}{n}=\frac{l^3}{n^3}\frac{n^3}{3}=\frac{l^3}{3}$$

The integral

$$\int_o^l x^3dx$$

yields to a similar treatment

$$\sum_o^l\left(m\frac{l}{n}\right)^3\frac{l}{n}=\frac{l^4}{n^4}[1^3+2^3+3^3+\ldots\ldots+n^3]$$

$$\begin{aligned}
n^4-(n-1)^4&=4n^3-6n^2+4n-1\\
(n-1)^4-(n-2)^4&=4(n-1)^3-6(n-1)^2+4(n-1)-1\\
(n-2)^4-(n-3)^4&=4(n-2)^3-6(n-2)^2+4(n-2)-1\\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\
(3)^4-(2)^4&=4(3)^3-6(3)^2+4(3)-1\\
(2)^4-(1)^4&=4(2)^3-6(2)^2+4(2)-1\\
(1)^4-(0)^4&=4(1)^3-6(1)^2+4(1)-1
\end{aligned}$$

Adding as in the previous case

$$n^4=4S_3-6S_2+4S_1-n$$

$$4S_3=n^4+n+n(n+1)(2n+1)-2n(n+1)$$

and, finally,

$$S_3=\left[\frac{n(n+1)}{2}\right]^2$$

Accordingly the value of the integral as n approaches infinity, is

$$\sum_o^l\left(m\frac{l}{n}\right)^3\frac{l}{n}=\frac{l^4}{n^4}\frac{n^4}{4}=\frac{l^4}{4}$$

The foregoing methods necessarily appear clumsy when it is considered that a general formula for a positive integral exponent

can be algebraically derived.* This general formula, however, requires a more extensive knowledge of algebraic series than is available from the course of study premised.

PROBLEMS IN MAXIMA AND MINIMA.

Plane of Rupture by Shear from Compression.—The angle of the plane of failure by shear in a short prismatic specimen subjected to compression is easily determined by the method of algebraic maximum.

Let A be the uniform cross-sectional area of the prism, Fig. 2, p, the compression force, S the shearing force along the plane

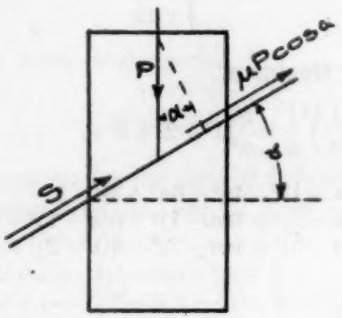


Fig. 2.

of failure—making the angle α with the normal plane, S_s, the unit shear, S_c the unit compression and μ, the coefficient of friction. Failure occurs along a plane at the angle α which makes the value of S_s a maximum when

$$S_c > S_s$$

From Fig. 2 the relationship of S_s, S_c and α is

$$S_c \tan \alpha = S_s(1+\tan^2 \alpha) + \mu S_c$$

and writing x for $\tan \alpha$

$$S_s x^2 - S_c x + S_s + \mu S_c = 0$$

from which

$$x = \frac{S_c \pm \sqrt{S_c^2 - 4S_s(S_s + \mu S_c)}}{2S_s}$$

* Treatise on Algebra—C. Smith.

The value of x for a maximum is

$$x=\frac{S_c}{2S}$$

where S_c and S_s are related by the equation

$$S_c^2-4S_s(S_s+\mu S_c)=0$$

Combining these two equations

$$x^2-2\mu x-1=0$$

and

$$\tan^2 a-2\tan\varphi\tan a-1=0$$

where

$$\mu=\tan\varphi$$

This reduces to

$$\frac{2\tan a}{1-\tan^2 a}=-\cot\varphi$$

or

$$\tan 2a=-\tan(90-\varphi)=\tan(90+\varphi)$$

and the value of a for maximum unit shear is

$$a=45°+\frac{\varphi}{2}$$

The formula for maximum resultant tension in a rectangular prism subjected to both tension and shear is of frequent application in the design of machine details. Though more complex than the preceding it can be derived by the same method.

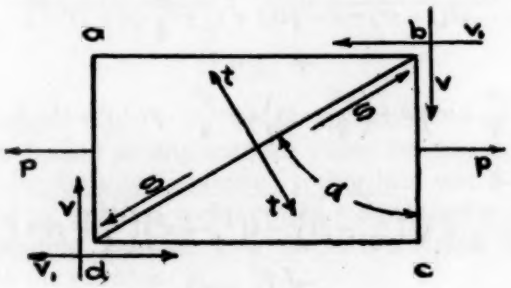


Fig. 3.

Unit tensile forces p are applied to the opposite faces $a\,d$ and $b\,c$ of the prism $a\,b\,c\,d$, Fig. 3.

The shearing unit stress v on the same faces are equilibrated by the equal unit shears v_1 on the faces $a\,b$ and $d\,c$.

These forces produce resultant unit tensions t and resultant unit shears S along the diagonal $b\,d$ making the angle α with the normal to p.

Resolving the forces in the direction of t, normal to $b\,d$

$$t\,bd = v\,ab\,\cos\alpha + v\,bc\,\sin\alpha + p\,bc\,\cos\alpha$$

Dividing by bd

$$t = 2v\,\sin\alpha\,\cos\alpha + p\,\cos^2\alpha$$

or

$$t = v\,\sin 2\alpha + \frac{p}{2}(\cos 2\alpha + 1)$$

Resolving the forces along bd

$$S\,bd = v\,ab\,\sin\alpha - v\,bc\,\cos\alpha + p\,bc\,\sin\alpha$$

and

$$S = v(\sin^2\alpha - \cos^2\alpha) + p\,\cos\alpha\,\sin\alpha$$

which may be written

$$S = \frac{p}{2}\,\sin 2\alpha + v\,\cos 2\alpha$$

Writing x for $\cos 2\alpha$

$$t = v\sqrt{1-x^2} + \frac{p}{2}\,(x+1)$$

Transposing and squaring

$$v^2(1-x^2) = t^2 - pt(x+1) + \frac{p^2}{4}(x+1)^2$$

or

$$\left(\frac{p^2}{4}+v^2\right)x^2 + \left(\frac{p^2}{2}-pt\right)x + \frac{p^2}{4} - pt + t^2 - v^2 = 0$$

Solving for x

$$x = \frac{pt - \frac{p^2}{2} \pm \sqrt{\left(\frac{p^2}{2}-pt\right)^2 - 4\left(\frac{p^2}{4}+v^2\right)\left(\frac{p^2}{4}-pt+t^2-v^2\right)}}{2\left(\frac{p^2}{4}+v^2\right)}$$

Making the quantity under the radical zero

$$-v^2t^2 + pv^2t + v^4 = 0$$

and

$$t=\frac{-pv^2\pm\sqrt{p^2v^4+4v^6}}{-2v^2}$$

which reduces to

$$t=\frac{p}{2}\pm\sqrt{\frac{p^2}{4}+v^2}$$

In a like manner it may be shown that the maximum resultant unit shear is

$$S=\sqrt{\frac{p^2}{4}+v^2}$$

Maximum Bending Moment for Beams.—The algebraic expression for moments on beams subjected to varying loads is generally of higher degree than the second and recourse must be had to the property that the area of the diagram for vertical shear is equivalent to the bending moment. This may be shown graphically from the shear diagram.

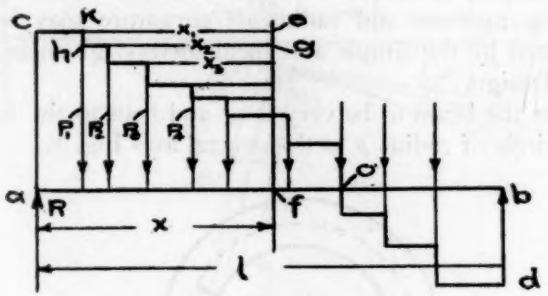


Fig. 4.

The stepped line *c o d*, Fig 4, represents the shear diagram of a beam loaded in any manner either by concentrated loads p_1, p_2, p_3, &c., or a continuously varying load which may also be represented by separate concentrated loads taken close together.

The bending moment at a distance x from the left end, where R is the reaction, is

$$M=Rx-p_1x_1-p_2x_2-p_3x_3+\&c.$$

The term Rx is represented by the area of the rectangle *a c e f* whose altitude is R and base x. Each product Px

diminishes the area Rx by a rectangle $k\ e\ g\ h$ forming a series of steps. The height of the steps is successively p_1, p_2, p_3, &c., and the height R at each point of application of load is diminished a like amount. That is the altitude of the diagram at any point is

$$R-\Sigma p$$

which represents the vertical shear.

It follows that the area of the vertical shear diagram for concentrated loads is equivalent to the bending moment. The same reasoning applies to continuous loads in which case the loads are small and separated by a minute interval. The steps then disappear and become a continuous slope.

At some point o, the area of the diagram ceases to increase for any increase of distance from a and at that point the area or the bending moment becomes a maximum.

DEFLECTION OF BEAMS.

In investigating the deflection of beams, the relation between the bending moment and radius of curvature may be readily demonstrated by the simple and lucid method given in Unwin's Machine Design.

Assume the beam to be very long and bent to the form of a complete circle of radius ρ at the neutral axis Fig. 5.

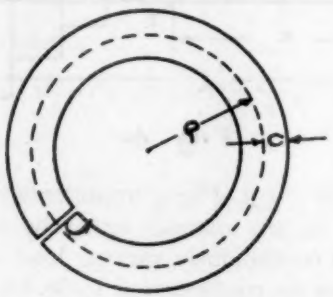


Fig. 5.

Let M be the bending moment, S, the unit stress at the most remote fibre, and c the distance of the most remote fibre from the neutral axis.

The length of the most remote fibre is $2\pi(\rho+c)$. The length of the neutral axis is $2\pi\rho$ and the extension due to bending is $2\pi c$. The extension per unit of length is consequently $\frac{c}{\rho}$ and

$$S=\frac{c}{\rho}E$$

where E is the coefficient of elasticity, and finally replacing S by $\frac{Mc}{I}$ where I is the moment of inertia

$$\rho=\frac{EI}{M}$$

GENERAL FORMULA FOR DEFLECTION.

A cantilever beam offers the simplest case of beam deflection. The beam is held horizontally at the point a Fig. 6, its initial

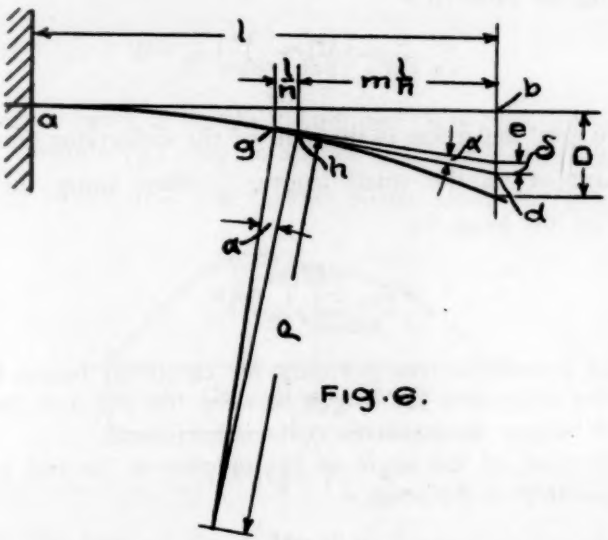


Fig. 6.

position being $a\,b$. Under the action of the loads it deflects at the end a distance D.

Suppose it to be divided into a large number of small parts, each $\frac{l}{n}$ long. At a distance from the end $m\frac{l}{n}$, the bending moment is M and the radius of curvature is ρ.

If the load were removed from the part $m\frac{l}{n}$ the axis would take the position $h\ d$ tangent to the elastic curve at h, and if, in addition, the load upon the small length $\frac{l}{n}$ were removed the axis would take the position $g\ e$ tangent at g.

It, at once, follows from the figure that the relation between the radius of curvature at $\frac{l}{n}$ and the deflection δ produced at the end of the beam is, by combining

$$\delta = \left(m\frac{l}{n}\right)a \quad \text{and} \quad \rho a = \frac{l}{n}$$

$$\delta = \frac{\left(m\frac{l}{n}\right)\frac{l}{n}}{\rho}$$

Inserting the value of ρ

$$\delta = \frac{M\left(m\frac{l}{n}\right)\frac{l}{n}}{EI}$$

and the total deflection is the sum of the deflections due to the curvature of all the small lengths $\frac{l}{n}$ taken along the entire length of the beam or

$$D = \sum_{o}^{l} \frac{M\left(m\frac{l}{n}\right)\frac{l}{n}}{EI} \tag{1}$$

This formula is true not only for cantilever beams but for all forms where l is the length between the end and the point where a tangent to the elastic curve is horizontal.

The value of the angle of the tangent at the end and the initial position of the beam is

$$\theta = \sum_{o}^{l} \frac{M\frac{l}{n}}{EI} \tag{2}$$

Formula (1) may be recognized as the *statical moment* of the bending moment diagram divided by EI, and (2) the *area* of the bending moment diagram divided by EI. These for subsequent reference will be expressed in the customary notation

$$D=\sum_{o}^{l}\frac{Mx\,dx}{EI} \tag{3}$$

$$\theta=\sum_{o}^{l}\frac{M\,dx}{EI} \tag{4}$$

In a simple beam uniformly loaded with a load ω per unit of length, the tangent to the elastic curve is horizontal at the centre and the limits of integration are $\frac{l}{2}$ and o. The bending moment

$$M=\frac{\omega lx}{2}-\frac{\omega x^2}{2}$$

Then by (3)

$$D=\frac{1}{EI}\sum_{o}^{\frac{l}{2}}\left(\frac{\omega lx^2}{2}-\frac{\omega x^3}{2}\right)dx$$

$$D=\frac{1}{EI}\left(\frac{\omega l^4}{48}-\frac{\omega l^4}{128}\right)=\frac{5}{384}\frac{\omega l^4}{EI}$$

When a beam is of the "built-up" type and of variable section, formula (3) may be applied graphically by plotting as in Fig. 7 values of $\frac{M}{I}$ for various points along the beam and

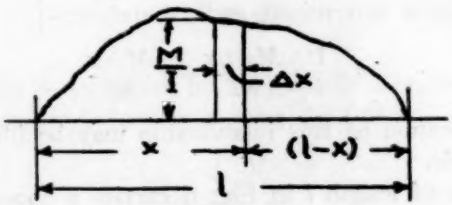


Fig. 7.

dividing the area of the diagram so formed to the point of maximum deflection, when the tangent to the elastic curve is horizontal, by E.

When the loading is irregular, the point of maximum deflection is not at the centre and the limits of summation must be determined. This may be done by the application of formula (4).

The beam represented in Fig. 8 has its maximum deflection at the unknown distance x from a. The tangent at the point b makes the angle θ with the horizontal ab, and its value may be found from (3)

$$\theta = \frac{D_1}{l} = \frac{1}{l} \sum_{o}^{l} \frac{Mx\triangle x}{EI}$$

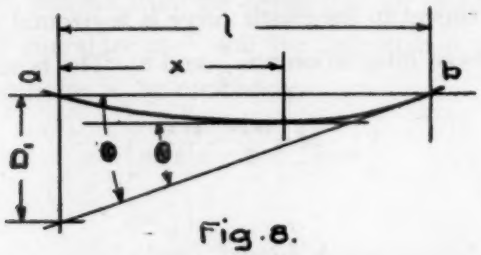


Fig. 8.

that is, the area of the statical moment diagram. This line makes the same angle with a tangent at the point x, and another value of θ from (4) is,

$$\theta = \sum_{x}^{l} \frac{M\triangle x}{EI}$$

by finding a distance $l - x$ subtending an area, from the moment diagram in Fig. 7, equivalent to the value of θ previously found.

The condition determining x is, therefore,

$$\theta = \frac{1}{l} \sum_{o}^{l} \frac{Mx\triangle x}{EI} = \sum_{x}^{l} \frac{M\triangle x}{EI} \qquad (5)$$

The application of this relationship may be illustrated by a simple example.

The beam of length l in Fig. 9 carries a concentrated load p at a distance $\frac{1}{4}l$ from the left end. The bending moment diagram is composed of two right triangles $a\,c\,d$ and $b\,c\,d$ with a common altitude $\frac{3}{16}\,pl$.

The statical moment of $a\,c\,b$ about a is

$$\frac{5}{128} pl^3$$

and

$$\frac{1}{l} \sum_{o}^{l} \frac{Mx\triangle x}{EI} = \frac{1}{EI} \frac{5}{128} pl^2$$

The area of the diagram between the limits of l and x,

$$\sum_{x}^{l} \frac{Mx\triangle x}{EI}$$

is

$$\frac{1}{EI}\frac{p}{8}(l-x)^2$$

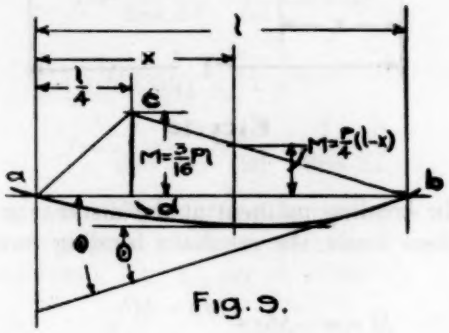
By (5)

$$\frac{p}{8}(l-x)^2 = \frac{1}{l}\left(\frac{5}{128}pl^3\right)$$

and

$$l-x = .559\ l.$$

If the area of the triangle $b\ c\ d$ were less than $\frac{5}{128}\ pl^2$, the distance x would fall on the left of the apex c and the algebraic ex-



pression would be simplified by integrating from the right end b.

The maximum deflection is, then, by (3)

$$D = \sum_{0.441\ l}^{l} \frac{Mx\triangle x}{EI}$$

or

$$D = 0.0246\frac{pl^3}{EI}$$

RESTRAINED BEAMS.

In the usual cases of symmetrical loading of restrained beams the end moments are equal. With unsymmetrical loading the end restraints are unequal and at any point distant x the moment may be expressed in terms of the moments at the ends.

The beam in Fig. 10 is acted upon at the ends by unequal and opposite moments Ma and Mb. These are held in equilibrium by the forces p at the supports constituting a couple pl equivalent to $Ma—Mb$. The force p acting on the side of the greater moment tends to diminish the reaction due to the superimposed load by the force

$$p=\frac{Ma-Mb}{l} \tag{6}$$

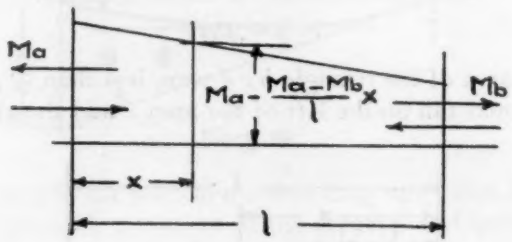


Fig. 10

If m is the bending moment at the distance x from the left end due to these loads, the resultant bending moment is

$$M=m-Ma+\frac{Ma-Mb}{l}x \tag{7}$$

When a restrained beam is uniformly loaded

$$Ma=Mb, \quad M=m-Ma, \quad \text{and} \quad m=\frac{\omega l}{2}-\frac{\omega x^2}{2}$$

Applying (3)

$$\theta=\frac{1}{E}\sum_{o}^{l}\left(\frac{\omega l}{2}x-\frac{\omega x^2}{2}-Ma\right)dx=0$$

and

$$\frac{\omega l^3}{4}-\frac{\omega l^3}{6}-Mal=0$$

from which

$$Ma=\frac{\omega l^2}{12}$$

At a distance x from the left end

$$M = \frac{\omega l}{2}x - \frac{\omega x^2}{2} - \frac{\omega l^2}{12}$$

When

$$x = \frac{l}{2} \quad M = \frac{\omega l^2}{8} - \frac{\omega l^2}{12} = \frac{\omega l^2}{24}$$

Making $M = o$, the points of inflection are

$$x = \frac{l}{2} \pm \sqrt{\frac{1}{12}}$$

The deflection at the centre is

$$D = \frac{5}{384}\frac{\omega l^4}{EI} - \frac{1}{EI}\sum_{o}^{\frac{l}{2}} Maxdx$$

$$D = \frac{5}{384}\frac{\omega l^4}{EI} - \frac{1}{8}Mal^2$$

$$D = \frac{5}{384}\frac{\omega l^4}{EI} - \frac{\omega l^4}{96} = \frac{1}{384}\frac{\omega l^4}{EI}$$

Theorem of Three Moments.—The moments at the points of support in the same plane of any two consecutive spans l_1 and l_2 of a continuous beam, Fig. 11, are A, B and C.

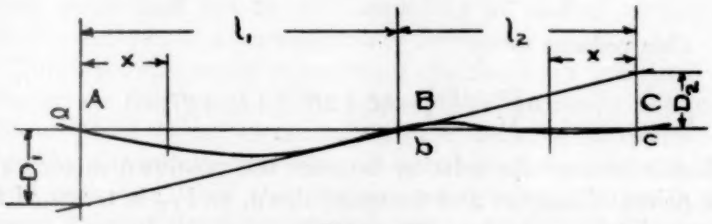


Fig. 11.

A tangent to the elastic curve at the middle support b intercepts lengths D_1 and D_2 on perpendiculars at the ends a and c.

Reckoning from the left support, a,

$$D_1 = \frac{1}{EI}\sum_{o}^{l_1}\left(m_1 - A + \frac{A-B}{l}x\right)xdx$$

In the same manner reckoning from the right support, c,

$$D_2=\frac{1}{EI}\sum_{o}^{l_2}\left(m_2-C+\frac{C-B}{l}x\right)xdx$$

when m_1 and m_2 are the moments of the superimposed loads.

From the figure

$$\frac{D_1}{l_1}=-\frac{D_2}{l_2}$$

and

$$\frac{1}{l_1}\sum_{o}^{l_1}\left(m_1-A+\frac{A-B}{l}x\right)xdx=-\frac{1}{l_2}\sum_{o}^{l_2}\left(m_2-C+\frac{C-B}{l}x\right)xdx$$

which may be written

$$\frac{1}{l_1}\left[\sum_{o}^{l_1}m_1xdx-\sum_{o}^{l_1}Axdx+\sum_{o}^{l_1}\frac{A-B}{l}x^2dx\right]=$$

$$-\frac{1}{l_2}\left[\sum_{o}^{l_2}m_2xdx-\sum_{o}^{l_2}Cxdx+\sum_{o}^{l_2}\frac{C-B}{l}x^2dx\right]$$

Writing μ_1 and μ_2 for the terms

$$\Sigma mxdx$$

and integrating the others,

$$\frac{\mu_1}{l_1}-\frac{Al_1}{2}+\frac{A-B}{3}l_1=-\frac{\mu_2}{l_2}+\frac{Cl_2}{2}-\frac{C-B}{3}l_2$$

This reduces to

$$6\left(\frac{\mu_1}{l_1}+\frac{\mu_2}{l_2}\right)=Al_1+2B\,(l_1+l_2)+Cl_2$$

which expresses the relation between the unknown moments at the points of support and the quantities μ_1 and μ_2 in terms of the known loads.

If a continuous beam of two equal spans with free ends bears a uniform load ω per unit of length

$$l_1=l_2,\ \mu_1=\mu_2=\sum_{o}^{l_1}m_1xdx=\sum_{o}^{l}\left(\frac{\omega l}{2}x-\frac{\omega x^2}{2}\right)xdx=\frac{\omega l^4}{24}$$

and (8) becomes

$$A+4B+C-\frac{\omega l^2}{2}=0$$

In a beam of three supports $A = C = 0$ and

$$B = \frac{\omega l^2}{8}$$

The end reactions are, from (6)

$$\frac{\omega l_1}{2} - \frac{\omega l}{8} = \frac{3}{8}\omega l$$

When the beam has four supports, the end moments A and D are zero and $B = C$, then

$$5B = \frac{\omega l^2}{2} \quad \text{and} \quad B = \frac{\omega l^2}{10}$$

The end reactions are

$$\frac{\omega l}{2} - \frac{\omega l}{10} = \frac{4}{10}\omega l$$

The formulas on deflection for simple and restrained beams and continuous beams as well are of a form more convenient for graphic application to irregular loading and variable section than those available in the text-books in general use.

The geometric method of derivation is probably applicable only when the bending moment is a function of x. When the moment is a function of y or both x and y, as in the investigation of the elastic equilibrium of columns, this method yields an unwieldy expression not at all comparable in ease of reduction with the differential equation usually employed.

The few representative problems discussed are presented to demonstrate that many of the beam problems usually accepted without proof in an elementary course may be satisfactorily solved by elementary methods. In some cases the solutions are found with less labor than by the usual methods, but, in its present state of development, it is not as broadly applicable to the general treatment of the subject.

It is a temporary expedient to be supplanted, it is hoped in the near future, by the organization of courses in technical and allied mathematical subjects of a grade in keeping with the standing of the Institute.

BOOK NOTICES

PENROSE'S PICTORIAL ANNUAL. A Review of the Graphic Arts, vol. xiv, 1908–9. The Process Year Book, edited by Wm. Gamble. London, A. W. Penrose & Co., Ltd., 1909, for sale in New York by Tennant & Ward.

The 14th volume of this well-known Annual has just come from the press. It contains the usual amount of interesting and valuable information for the process worker and the tricolor printer. Many illustrations are included which serve as specimens of the numerous processes which the book describes. R.

DIE ENGLISCHEN ELEKTROCHEMISCHEN PATENTE. Auszuege aus den Patentschriften, zusammengestellt und mit ausfuehrlichem Sach-und Namenregister versehen von Dr. P. Ferchland, Patentanwalt in Berlin. Erster Band: Elektrolyse. Mit vielen Figuren im Text. Halle a S. Verlag von Wilhelm Knapp 1907. Paper, price 9 marks.

The 29th volume of the Monographien ueber angewandte Elektrochemie is a review of the English patents on Electro Chemistry. It corresponds in arrangement with the same author's volume of German Electro Chemical Patents issued some time ago. The earliest patent contained in the present volume is dated 1842 and the abstracts are brought down to the end of 1906. The work will be in several volumes of which this is the first. As a reference book it will be extremely useful. R.

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Pennsylvania Department of Agriculture. The Zoological Bulletin of the Division of Zoology. September 1, October 1, November 2, December 1, 1908. 4 pamphlets, illustrations, 8vo. Harrisburg, State printer, 1908.